U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

PB-286 566

Investigation of Remote Sensing Techniques for Agricultural Feedlot Pollution Detection

South Dakota State Univ, Brookings Remote Sensing Inst

Prepared for

Environmental Protection Agency, Washington, DC

Dec 73

EPA-670/4-73-002
December 1973

PB 286 566

INVESTIGATION OF REMOTE SENSING TECHNIQUES FOR AGRICULTURAL FEEDLOT POLLUTION DETECTION

Remote Sensing Institute
South Dakota State University
Brookings, South Dakota

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U. S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO.
EPA-670/4-73-002

2.

3. RECIPIENT'S ACCESSION NO.
PB286566

4. TITLE AND SUBTITLE
INVESTIGATION OF REMOTE SENSING TECHNIQUES FOR AGRICULTURAL FEEDLOT POLLUTION DETECTION

5. REPORT DATE
December 1973 issuing date

6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)
FRED A. SCHMER, DENNIS W. RYLAND & FRED A. WALTZ

8. PERFORMING ORGANIZATION REPORT NO.

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Remote Sensing Institute
South Dakota State University
Brookings, South Dakota 57006

10. PROGRAM ELEMENT NO.

11. CONTRACT/GRANT NO.
Grant - #16020FPH

12. SPONSORING AGENCY NAME AND ADDRESS
United States Environmental Protection Agency
Department of the Interior
Washington, DC 20460

13. TYPE OF REPORT AND PERIOD COVERED

14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES
SDSU-RSI-72-14 Project Officer: Ronald Ritter, U.S. ENVIRONMENTAL PROTECTION AGENCY
REGION 7, KANSAS CITY MO 64108

16. ABSTRACT

This research effort was directed toward the application of remote sensing techniques to the detection and monitoring of pollution from cattle feeding operations. Five livestock feedint operations were selected for the study along the James River from Huron to Redfield, South Dakota. Thirteen aerial missions were flown from January 1, 1971 through June 30, 1972, providing aerial photography and thermal infrared data under various weather conditions. Water samples were collected during nine of the aerial flights at fourteen river locations. Water samples were collected a minimum ofevery three weeks on a regular schedule to allow independent analysis of the water quality data.

Data analysis consisted of visual interpretation of aerial photography and statistical analysis of film densities and water quality parameters. Film densities were read at the location of the fourteen water sampling sites and correlated with the water quality parameters. Analysis of variance and linear regression techniques were also utilized. In addition an attempt was made to adjust the film densities for variations in incoming radiation.

Results indicated that remote sensing techniques utilizing low and high altitude aircraft photography can be used to locate potential feedlot pollution sources.

The statistical analysis showed good results for specific aerial flights indicating that additional study is warranted.

This report was submitted in fulfillment of Grant No. 16020 FPH by the Remote Sensing Institute, South Dakota State University, Brookings, South Dakota, under the sponsorship of the Environmental Protection Agency. Work was completed as of June 30, 1972.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Remote Sensing Agricultural Feedlot Pollution		

18. DISTRIBUTION STATEMENT
Release to Public

19. SECURITY CLASS *(This Report)*
UNCLASSIFIED

20. SECURITY CLASS *(This page)*
UNCLASSIFIED

21. NO. OF PAGES
178

22. PRICE
A09-A01

EPA Form 2220-1 (9-73)

EPA-670/4-73-002
December 1973

INVESTIGATION OF REMOTE SENSING TECHNIQUES FOR AGRICULTURAL FEEDLOT POLLUTION DETECTION

Remote Sensing Institute
South Dakota State University
Brookings, South Dakota 57006

1a

EPA-670/4-73-002
December 1973

INVESTIGATION OF REMOTE SENSING TECHNIQUES FOR AGRICULTURAL FEEDLOT POLLUTION DETECTION

by

Fred A. Schmer, Dennis W. Ryland and Fred A. Waltz

to

United States
Environmental Protection Agency
Department of the Interior
Washington, D.C.
Grant #16020 FPH

Remote Sensing Institute
South Dakota State University
Brookings, South Dakota 57006

April, 1973

ib

ABSTRACT

This research effort was directed toward the application of remote sensing techniques to the detection and monitoring of pollution from cattle feeding operations. Five livestock feeding operations were selected for the study along the James River from Huron to Redfield, South Dakota. Thirteen aerial missions were flown from January 1, 1971 through June 30, 1972, providing aerial photography and thermal infrared data under various weather conditions. Water samples were collected during nine of the aerial flights at fourteen river locations. Water samples were collected a minimum of every three weeks on a regular schedule to allow independent analysis of the water quality data.

Data analysis consisted of visual interpretation of aerial photography and statistical analysis of film densities and water quality parameters. Film densities were read at the location of the fourteen water sampling sites and correlated with the water quality parameters. Analysis of variance and linear regression techniques were also utilized. In addition an attempt was made to adjust the film densities for variations in incoming radiation.

Results indicated that remote sensing techniques utilizing low and high altitude aircraft photography can be used to locate potential feedlot pollution sources. The statistical analysis showed good results for specific aerial missions but considerable variability was noted between aerial flights indicating that additional study is warranted.

This report was submitted in fulfillment of Grant No. 16020 FPH by the Remote Sensing Institute, South Dakota State University, Brookings, South Dakota, under the sponsorship of the Environmental Protection Agency. Work was completed as of June 30, 1972.

TABLE OF CONTENTS

Page

ABSTRACT ii

TABLE OF CONTENTS iv

LIST OF FIGURES vi

LIST OF TABLES. ix

INTRODUCTION. 1

    Objectives 1

LITERATURE REVIEW 2

RESEARCH METHODOLOGY. 4

    Multispectral Sensing. 4

    Statistical Methods. 7

    Film Density Adjustment. 8

PROCEDURE AND DATA COLLECTION 11

    Project Area Selection and Description 11

    Aerial Data collection 19

    Ground Truth Data Collection 23

ANALYSIS AND RESULTS. 26

    Water Quality Analysis 26

    Film Density - Water Quality Analysis. 29

    Thermal Imagery Analysis 36

    Visual Analysis. 41

CONCLUSIONS AND RECOMMENDATIONS 58

    Recommendations For Further Study. 59

REFERENCES. 61

TABLE OF CONTENTS (Continued)

Page

PUBLICATIONS. 63

APPENDIX. 64

A. 65

B. 70

C. 72

D. 115

LIST OF FIGURES

FIGURE PAGE

1. (a) The electromagnetic spectrum; and (b) a portion of the electromagnetic spectrum commonly associated with remote sensing measurements in agriculture and hydrology (4). 5

2. Multispectral prints of the same area taken May 4, 1972, 1067 m agl, scale: 1 cm = 211 m. 6

3. Spectral distribution of solar radiation at sea level for a clear day from Gates (6) 9

4. Location of James River and project area in South Dakota 12

5. Location of feedlots and sampling sites in southern half of project area. Feedlots designated by letters and sampling sites by numbers. 13

6. Location of feedlots and sampling sites in northern half of project area. Feedlots designated by letters and sampling sites by numbers. 14

7. Feedlot site A from 70 mm color film, #2448 with HF3 filter, taken May 26, 1972, 1067 m agl, 3X enlargement, scale: 1 cm = 70.5 m. 15

8. Feedlot site A from 70 mm color film, #2448 with HF3 filter, taken May 4, 1972, 1067 m agl, 3X enlargement, scale: 1 cm = 70.5 m. 16

9. Feedlot site B from 70 mm color film, #2448 with HF3 filter, taken April 29, 1971, 1067 m agl, 3X enlargement, scale: 1 cm = 70.5 m. 17

10. Feedlot site C from 70 mm color film, #2448 with HF3 filter, taken May 26, 1971, 1967 m agl, 3X enlargement, scale: 1 cm = 70.5 m. 18

11 Feedlot site D from 70 mm color film, #2448 with HF3 filter, taken April 19, 1971, 1067 m agl, 3X enlargement, scale: 1 cm = 70.5 m. 20

12. Feedlot site E from 70 mm color film, #2448 with HF3 filter, taken June 11, 1971, 1067 agl, 4X enlargement scale: 1 cm = 52.7 m. 21

FIGURE PAGE

13. Print from color film, #2448 with HF3 filter showing effects of cloud cover and sunglint, June 11, 1971, 1067 m agl, scale: 1 cm = 211 m 24

14. Print from color film, #2448 with HF3 filter taken with favorable conditions on May 26, 1971, 1067 m agl, scale: 1 cm = 211 m 24

15. Mission correlation coefficients plotted against time for the black and white film with green filter, #58 . 34

16. Mission correlation coefficients plotted against time for the color infrared films, #2443 with a red densitometer filter 35

17. Thermal infrared print showing a section of the James River scanned on August 19, 1971, 1067 m agl, scale: 1 cm = 500 m. 39

18. Print from 70 mm color film, #2448 with HF3 filter, taken March 8, 1972, 1067 m agl, 3X enlargement, scale: 1 cm = 70.5 m 42

19. Ground truth photograph of feedlot shown in Figure 18, March 13, 1972. 43

20. Ground truth photograph of feedlot shown in Figure 18, March 13, 1972. 43

21. Print from 70 mm color film, #2448 with HF3 filter taken March 8, 1972, 1067 m agl, 3X enlargement, scale: 1 cm = 70.5 m. 44

22. Print from thermal scan showing feedlot site A on March 18, 1972, 1067 m agl, scale: 1 cm = 169 m 41

23. Ground truth photograph of area shown in Figure 21, March 13, 1972. 46

24. Ground truth photograph of area shown in Figure 21, March 13, 1972. 46

25. Print from 70 mm color film, #2448 with HF3 filter, taken March 8, 1972, 1067 m agl, 5X enlargement, scale: 1 cm = 42.2 m 47

26. Ground truth photograph of area shown in Figure 25, March 13, 1972. 48

FIGURE PAGE

27. Ground truth photograph of area shown in Figure 25, March 13, 1972 48

28. Print from 70 mm color film, #2448 with HF3 filter, taken March 8, 1972, 1067 m agl, 3X enlargement, scale: 1 cm = 70.5 m 49

29. Ground truth photograph of feedlot shown in Figure 28, March 13, 1972 50

30. Ground truth photograph of feedlot shown in Figure 28, March 13, 1972 50

31. Print from 70 mm color film, #2448 with HF3 filter, taken March 8, 1972, 1067 m agl, 4.3X enlargement, scale: 1 cm = 49 m 51

32. Ground truth photograph of feedlot shown in Figure 31, March 13, 1972 52

33. Ground truth photograph of stream flowing into James River located next to feedlot shown in Figure 31, March 13, 1972 52

34. Print from NASA RB-57 Mission #146 taken on November 5, 1970, with color infrared film #2443, 18,300 m (60,000 feet) agl, 1X enlargement. 53

35. Print from NASA RB-57 Mission #146 taken on November 5, 1970, with color infrared film #2443, showing feedlot #1 from Figure 34, 18,300 m (60,000 feet) agl, 19X enlargement. 54

36. Print from NASA RB-57 Mission #146 taken on November 5 1970, with color infrared film #2443, 18,300 m (60,000 feet) agl, 1X enlargement. 55

37. Print from NASA RB-57 Mission #146 taken on November 5, 1970, with color infrared film #2443, showing feedlot 9 from Figure 36, 18,300 m (60,000 feet) agl, 16X enlargement. 57

TABLE PAGE

1. REMOTE SENSING AERIAL DATA COLLECTION 22

2. ANALYSIS OF VARIANCE OF WATER QUALITY PARAMETERS. . . 26

3. SUMMARY OF SIGNIFICANCE TESTS FOR ANALYSIS OF VARIANCE OF WATER QUALITY PARAMETERS 27

4. COMPARISON OF WATER QUALITY CRITERIA AND OBSERVED WATER QUALITY OF THE JAMES RIVER. 28

5. ANALYSIS OF VARIANCE OF FILM DENSITIES. 30

6. ANALYSIS OF VARIANCE OF COLOR AND COLOR INFRARED FILM DENSITIES. 30

7. CORRELATION COEFFICIENTS FOR FILM DENSITIES AND WATER QUALITY PARAMETERS FOR NINE DATA COLLECTION MISSIONS. 32

8. CORRELATION COEFFICIENTS FOR ADJUSTED FILM DENSITIES AND WATER QUALITY PARAMETERS FOR NINE DATA COLLECTION MISSIONS. 37

9. CORRELATION COEFFICIENTS FOR THERMAL INFRARED FILM DENSITIES AND WATER QUALITY PARAMETERS FOR FOUR AERIAL MISSIONS 40

INTRODUCTION

Pollution and its effect on our environment concerns all of us. Agriculture is receiving its share of attention with runoff from livestock feeding operations as one of the most obvious forms of agricultural pollution. Laws and regulations to control runoff and discharge into our water resources have been enacted, but before they can be effectively enforced, improved techniques are needed to locate and monitor pollution sources.

This research effort was concerned with techniques of detecting and monitoring agricultural feedlot pollution. Feedlots along the James River in east central South Dakota were selected for study. Low altitude aerial photography and thermal infrared remote sensing techniques were utilized during all seasons of the year. Water samples were collected to provide an indication of the water quality of the river and the presence of pollution from the feedlots. The use of high altitude photography was also investigated.

Objectives

The specific objectives of this research effort were:

1. To investigate the applicability of remote sensing techniques for locating potential feedlot pollution sources, and
2. To investigate the applicability of remote sensing techniques for determining the movement of potential feedlot pollutants.

LITERATURE REVIEW

Some agricultural wastes have been studied in detail; however, except for the last few years, little attention has been given to water pollution resulting from agricultural enterprises such as feedlots. In 1968, Loehr (8) made a study "to develop a forward oriented review of the animal waste problem and its inherent pollution potential". He made recommendations involving the activities for the control and abatement of animal wastes. Data compiled by Loehr showed that the waste population equivalent of feeder cattle is greater than the human population in each of the ten Missouri River Basin States.

In 1971 a national symposium on "Animal Waste Management" (1) was held to bring researchers and various state, federal, and private agencies together to share experiences, knowledge, and concerns about animal waste management. Recommendations were formulated concerning information, education, and training programs; technical and financial assistance; research and development; and legislation and regulation. Special consideration was given to the problems faced by farmers and ranchers in meeting pollution laws and regulations. Recommendations for the utilization of remote sensing suggested that state and federal agencies use presently available equipment and techniques, and that research be continued to develop new instruments for reliable unattended operation for monitoring pollution.

Ryerson and Wood (10) demonstrated the use of remote sensing techniques to determine the type of cattle operation being practiced on farms in southern Ontario and the number of cattle found on each farm. Black and white photographs were used to identify crop types grown by each farm operator and the size and types of buildings on each farmstead. With this information it was determined whether the operation was of the beef or dairy type. Although not concerned directly with feedlot pollution the work by Ryerson and Wood does illustrate the potential of remote sensing techniques for locating potential sources of pollution.

Photographic experiments in oceanographic sensing reported by Helgeson and Ross (7) revealed that there is useful information on water in the blue region of the spectrum. Standard practice has been to eliminate hazelight below 0.50 μ with a blue cutoff filter. Helgeson and Ross suggested that the red sensitive layer be omitted from color infrared film rather than blue because red-light energy is absorbed by the water and therefore limited information is recorded from below the water surface.

The fact that the blue part of the spectrum permits greater depth penetration was demonstrated in an experiment conducted in 1969 with a submersible vehicle (9). The vehicle was submerged to depths of 10, 15, and 25 meters. A 13 x 28 foot white area on the submersible was photographed with a four-lens multispectral camera in the blue, green, red and blue-green bands. Detection of the submersible ceased at 30 meters in the green band while the blue and blue-green band permitted penetration to 35 meters.

Research is currently being conducted at the University of Wisconsin (11) on the applicability of monitoring water quality by remote sensing techniques. A spectrophotometer is used to measure the percent reflectance of various samples of water from 0.2 μ to 1.2 μ in the spectrum. Distinctive reflectance curves were obtained for water samples of wastes from municipalities, milk plants, paper mills, tanneries, canning factories and also samples from various lakes. Correlation of the reflectance curves with imagery of pollution being discharged into the Wisconsin River from a paper mill was attempted. Kodak Film Type 8443 with a Kodak Wratten #4 filter was found to be best for the detection of the paper mill waste and municipal wastes.

Feinstein and Piech (5) presented evidence of multiple scatter effects on the remote sensing of water pollution. Polluted bodies of water were shown to be optically thick media in which multiple scatter effects play a significant role in light propogation. Determining the concentration of a pollutant with remote sensing techniques is dependent upon the accurate measurement of spectral reflectances. They suggest that through the proper use of ground truth data and the inclusion of multiple scatter effects pollutant concentrations can be evaluated.

RESEARCH METHODOLOGY

Multispectral Sensing

Remote sensing is the applied science of remotely detecting and interpreting the results of the interaction of electromagnetic energy with the earth's mantle or atmosphere. Figure 1 shows the electromagnetic spectrum and the portions of the spectrum commonly associated with remote sensing measurements in agriculture and hydrology. The most familiar instrument used to record this energy is the photographic camera. The camera records electromagnetic energy within specific spectral bands determined with the use of various film and filter combinations. Three types of photographic film commonly used are panchromatic or black and white, color, and color infrared. Panchromatic film has one emulsion layer that absorbs radiation over the visible portion of the electromagnetic spectrum. Filters are used to record information within specific spectral bands.

Color film has three emulsion layers sensitive to blue, green, and red radiation. Filters normally used with the color film are haze filters which eliminate the excess bluishness caused by atmospheric attenuation.

Color infrared film with three emulsion layers is sensitive to green, red, and near infrared radiation. The green layer is also sensitive to a portion of the blue radiation but this is generally eliminated with a filter. In addition a color compensating filter is often used with color infrared film to accentuate the infrared portion of the spectrum.

Figure 2 shows four multispectral prints of the same area taken simultaneously with four Hasselblad cameras. The multispectral combinations illustrated in Figure 2 were generally used for this research effort.

A thermal infrared scanner system was also utilized to collect data. Thermal infrared sensing exploits the fact that all materials above absolute zero (minus 273 degrees Centigrade) emit radiation in quantities and wavelengths that depend on the nature of the surface, its emissivity, and its temperature. The output of the scanner can be recorded on a film where the patterns of gray tones represent temperature-emissivity differences.

Following the exposure and development of the multispectral photographic imagery a method is needed to characterize or determine what levels are recorded on the film. The measurement of film densities with a transmission densitometer is one method of accomplishing this task. The densitometer measures the amount of light

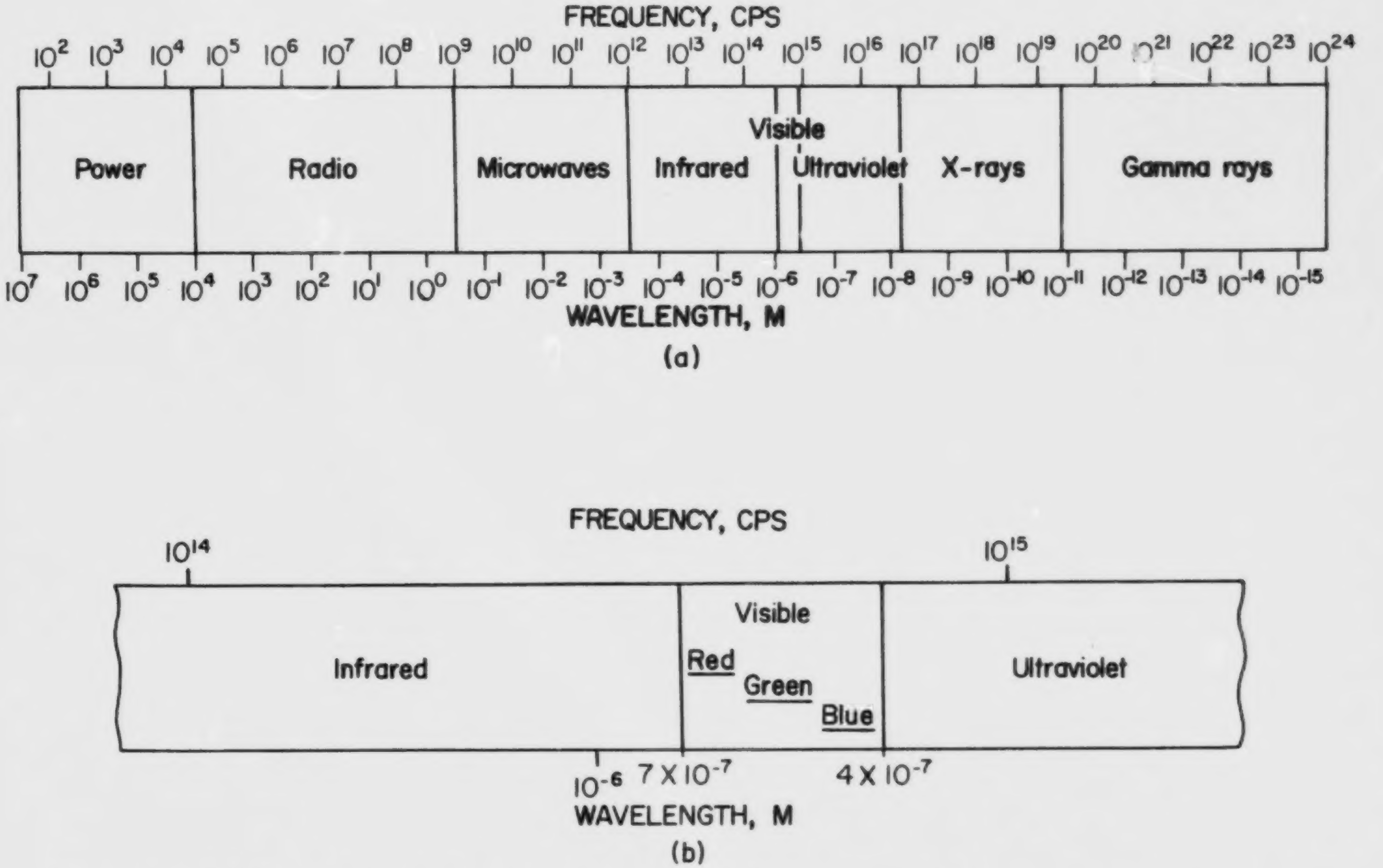
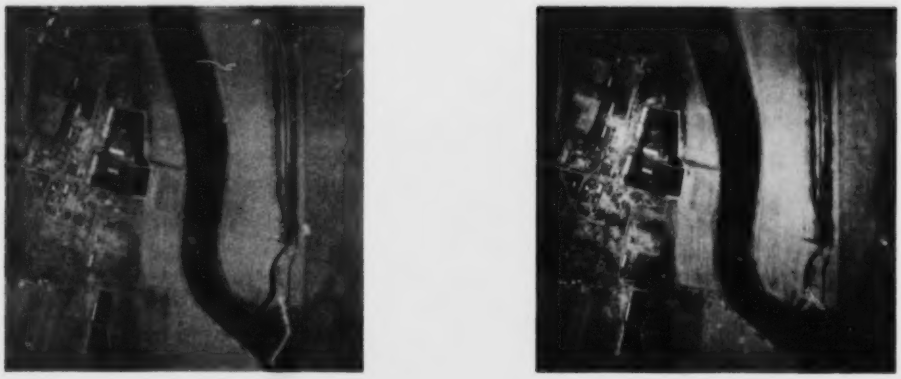
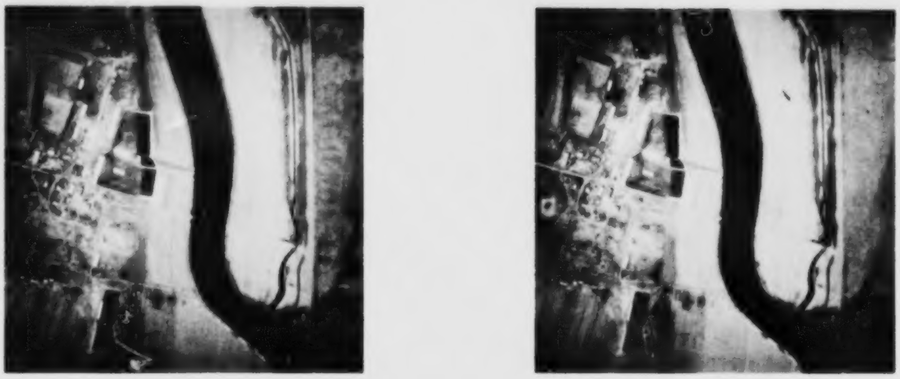

FREQUENCY, CPS
10^2 10^3 10^4 10^5 10^6 10^7 10^8 10^9 10^{10} 10^{11} 10^{12} 10^{13} 10^{14} 10^{15} 10^{16} 10^{17} 10^{18} 10^{19} 10^{20} 10^{21} 10^{22} 10^{23} 10^{24}
Power
Radio
Microwaves
Infrared
Visible
Ultraviolet
X-rays
Gamma rays
10^7 10^6 10^5 10^4 10^3 10^2 10^1 10^0 10^{-1} 10^{-2} 10^{-3} 10^{-4} 10^{-5} 10^{-6} 10^{-7} 10^{-8} 10^{-9} 10^{-10} 10^{-11} 10^{-12} 10^{-13} 10^{-14} 10^{-15}
WAVELENGTH, M
(a)
FREQUENCY, CPS
10^{14}
10^{15}
Infrared
Visible
Red
Green
Blue
Ultraviolet
10^{-6}
7×10^{-7}
4×10^{-7}
WAVELENGTH, M
(b)

Figure I. (a) The electromagnetic spectrum; and (b) a portion of the electromagnetic spectrum commonly associated with remote sensing measurements in agriculture and hydrology (4).



(a) Color film #2448 with HF3 filter

(b) Color infrared film #2443 with G15/30M filter



(c) Black and white film #2402 with #47B filter

(d) Black and white film #2402 with #58 filter

Figure 2. Multispectral prints of the same area taken May 4, 1972, 1067 m agl, scale: 1cm=211 m.

transmitted through the film for aperture settings of one, two, or three millimeters. In addition the densitometer is equipped with four filters (total, red, green, and blue) which transmit light for specific spectral bands. The densitometer filter designated "total" in this report is many times referred to as a "neutral" density filter. This filter allows light transmission throughout the visible portion of the spectrum but the light source is adjusted by the filter depending on the specific characteristics of filter used.

For color and color infrared film all four densitometer filters are used. The total filter gives an overall film density. The red, green, and blue filters allow measurement of film density for each of the three layers of color and color infrared film. It should be noted that for color infrared film the blue densitometer filter gives the response due to the green portion of the spectrum, the green filter gives the response due to the red portion, and the red filter gives the response due to the near infrared portion.

For the film-filter combinations shown in Figure 2, ten film densities were recorded for a specific location on the film. The ten densities consist of one for each black and white film and four for each of the color and color infrared films.

Statistical Methods

Statistical methods used for the analysis of the water quality parameter data and the film densities included analysis of variance, linear correlation and linear regression. F-tests were used with the analysis of variance to indicate which sources of variation were significant at the one and five percent levels. Means were also used to aid in the interpretation of the analysis of variance results.

The comparison between the film densities and the water quality parameters was accomplished by using linear correlation. Correlation is a measure of the degree to which variables vary together (13). A correlation coefficient of +1 indicates that as one variable changes the other variable changes identically. A correlation coefficient of -1 indicates that as one variable increases the other variable decreases identically. A correlation coefficient of zero indicates that there is no relation between the variables. Correlation coefficients were computed for each aerial mission and for all aerial missions combined.

The ability to predict one variable knowing the value of another variable can be evaluated with linear regression techniques. The regression equation gives the best functional relation among the variables. Regression equations were developed for data from each aerial mission and for all missions combined.

Film Density Adjustment

To correlate between water quality and film density, variables affecting film density other than water quality need to be considered. Optical density of film is dependent upon the amount of radiation reflected from the surface being photographed. Multispectral photography measures the reflected radiation within the specific spectral bands as determined by the band-pass filters. The spectral radiance within a specific band, $R_{s\ band}$, can be determined by the following formula:

$$R_{s\ band} = RF\ (R_s)$$

where

RF = fraction of the total incoming radiation from a spectral band

R_s = total incoming radiation

The fraction of radiation within a spectral band, RF, can be estimated from Figure 3 by integrating the area under the curve for each film-filter combination and dividing the total area under the curve. The total incoming radiation, R_s, is obtained with a solameter mounted on the top of the aircraft.

To continue the analysis the following limiting assumptions were made:

1. The spectral reflectance of the reflecting surface, or water for this study, was constant throughout the data collection period except for the variation caused by changes in water quality.
2. The spectral distribution of the incoming radiation was constant throughout the data collection period.

With the above assumptions the adjusted film density, DC, for color and color infrared film, which are positive type films, is obtained by:

$$DC = R_{s\ band}\ (D)$$

where

$R_{s\ band}$ = spectral radiance within a spectral band

D = Film density

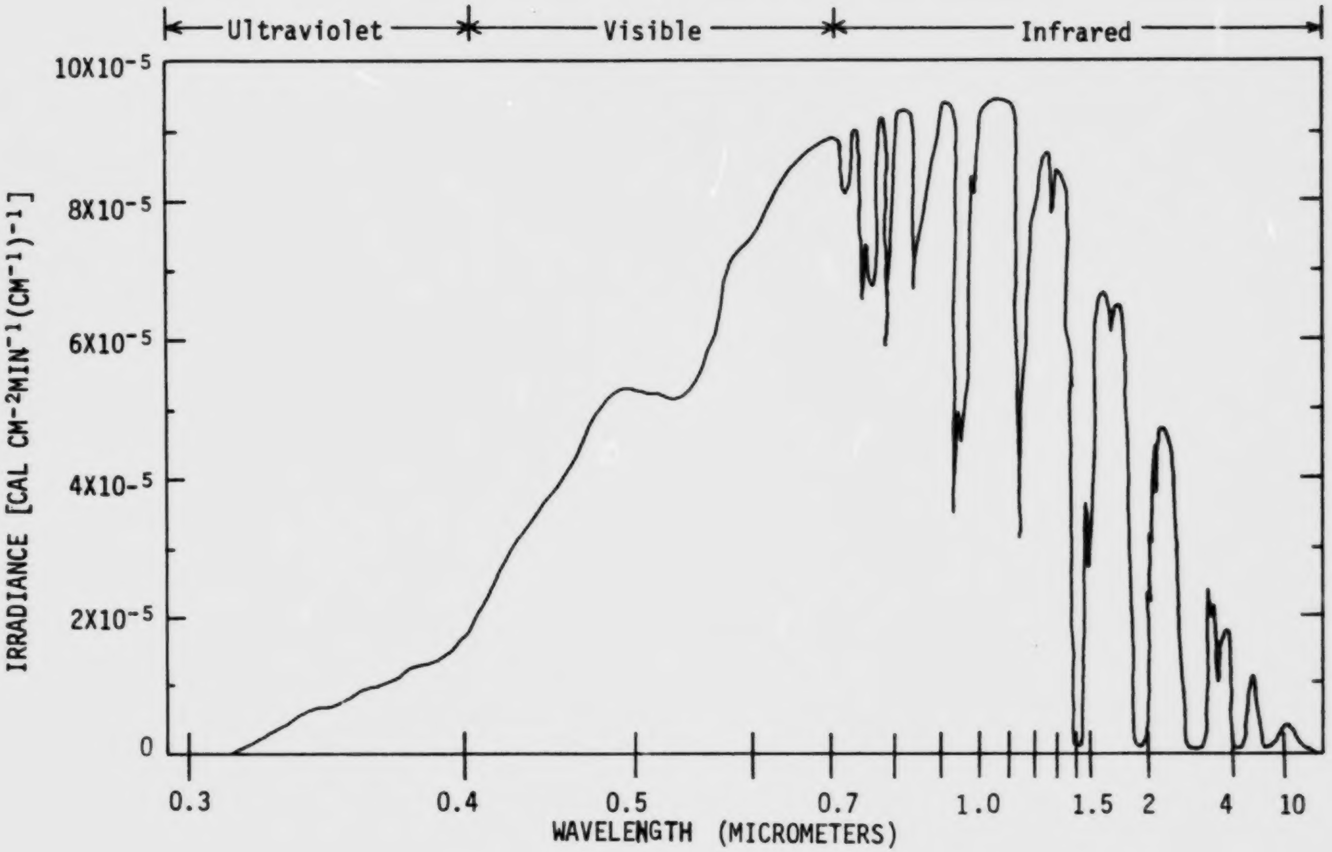


Figure 3. Spectral distribution of solar radiation at sea level for a clear day from Gates (6).

For the black and white film, which is negative type film, the adjusted density is obtained by:

$$DC = R_{s\ band}(\frac{1}{D})$$

The procedures outlined above were used in work conducted by Werner (14). It should be noted that the use of the inverse of the unadjusted film density (1/D) for the black and white film is an emperical transformation and not a linear film density adjustment for variations in incoming radiation.

The adjusted densities for the black and white film, color film and color infrared film were used to correlate with the water quality parameters for each aerial mission and for all the aerial missions combined.

PROCEDURE AND DATA COLLECTION

Project Area Selection and Description

The James River, located in central South Dakota and flowing from north to south across the state, was selected as the primary project site. Figure 4 shows the location of the river in South Dakota. Potential feedlot pollution sources were selected along the James River based upon a preliminary remote sensing aerial mission in April, 1970. This flight was made in cooperation with the Federal Water Pollution Control Administration, the South Dakota Department of Health and the Remote Sensing Institute.

The climate of the area can be considered semi-arid. Average annual precipitation is 48 cm (19 inches) with 65 percent of the total moisture falling during the growing season from April through August. The monthly precipitation amounts in 1971 for Huron and Redfield are presented in Table A1 of Appendix A. The terrain of the area is extremely level. The slope of the James River is 6.3 to 9.5 centimeters per kilometer (4 to 6 inches per mile) causing an average stream flow of approximately seven cubic meters per second (250 cfs) during the peak runoff periods of April and May.

From the preliminary aerial photographs and ground observations five feeding operations were selected for sequential aerial and ground truth data collection. These sites were selected on the basis of potential pollution hazard, accessibility to sampling sites, size of feeding operation and cooperation of the operators involved. Figures 5 and 6 show the location of the five feedlots. Feedlot sites were lettered from A through E moving in a south to north direction along the James River.

Site A, shown in Figure 7, is a 200 head confined dairy feeding operation located 200 meters from the James River. Prior to August 1, 1971, all runoff from the feedlot flowed directly to the river. During August settling ponds were constructed between the feedlots and the river to alleviate the runoff problem. Figure 8 is a photograph taken in May, 1972, showing the settling ponds following a period of heavy rainfall.

Site B, shown in Figure 9, is a 250 beef cow and calf feeding unit located next to a stream flowing into the James River. The cattle are fed in the lots during the winter and pastured in the summer. Feedlots located farther upstream from Site B may also be potential polluters.

Site C, shown in Figure 10 is a beef feeding operation of approximately 100 feeders. All runoff from the feedyard flows into a drainageway and directly to the James River. No attempt to date

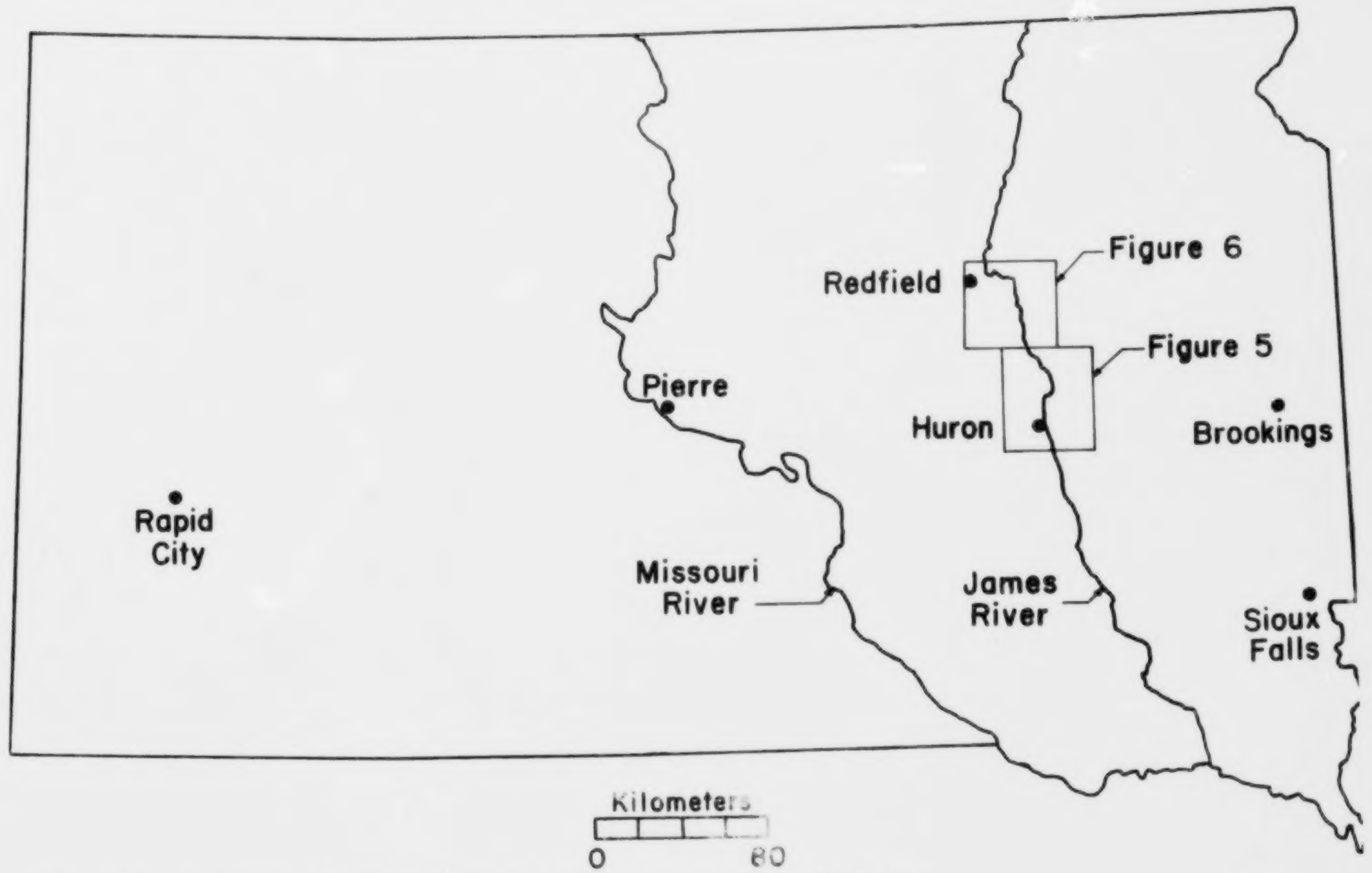


Figure 6
Figure 5
Redfield
Pierre
Huron
Brookings
Rapid City
Missouri River
James River
Sioux Falls
Kilometers
0
80

Figure 4. Location of James River and project area in South Dakota

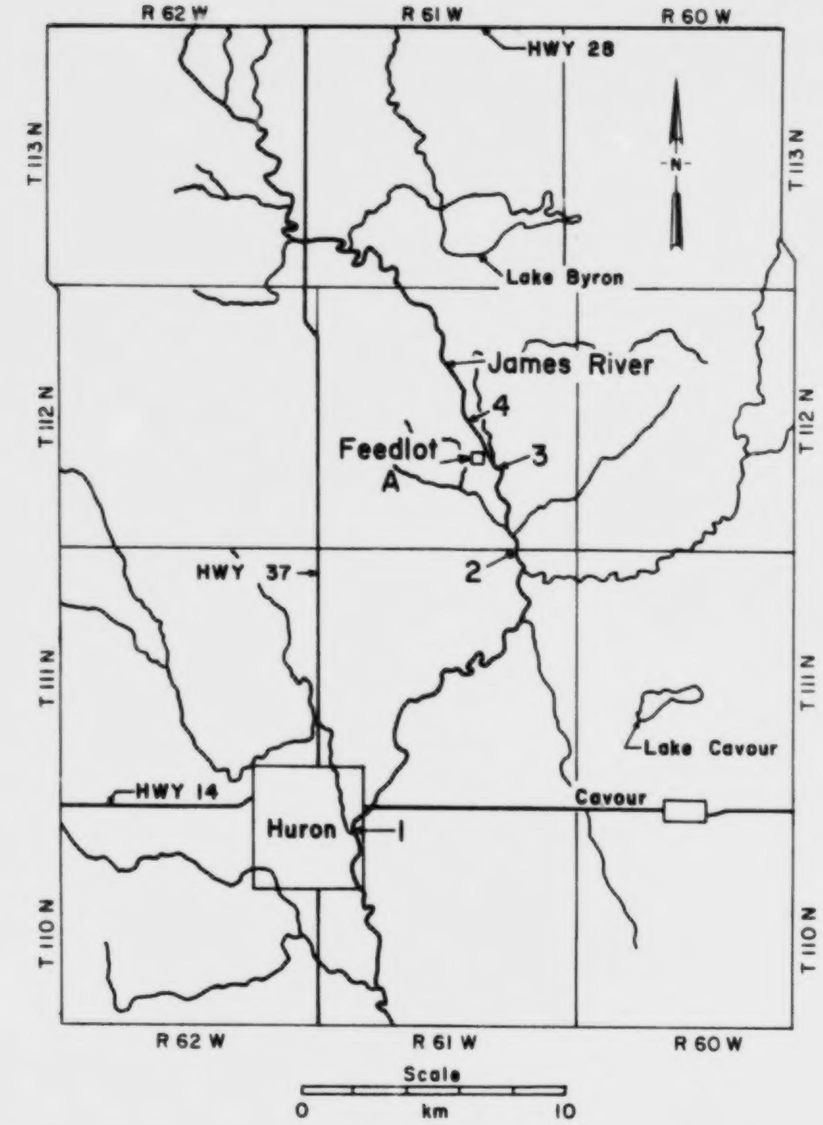

R 62 W
R 61 W
R 60 W
HWY 28
N
T 113 N
T 113 N
Lake Byron
James River
4
T 112 N
T 112 N
Feedlot
A
3
HWY 37
2
T 111 N
T 111 N
Lake Cavour
HWY 14
Cavour
Huron
1
T 110 N
T 110 N
R 62 W
R 61 W
R 60 W
Scale
0
km
10

Figure 5. Location of feedlots and sampling sites in southern half of project area. Feedlots designated by letters and sampling sites by numbers.

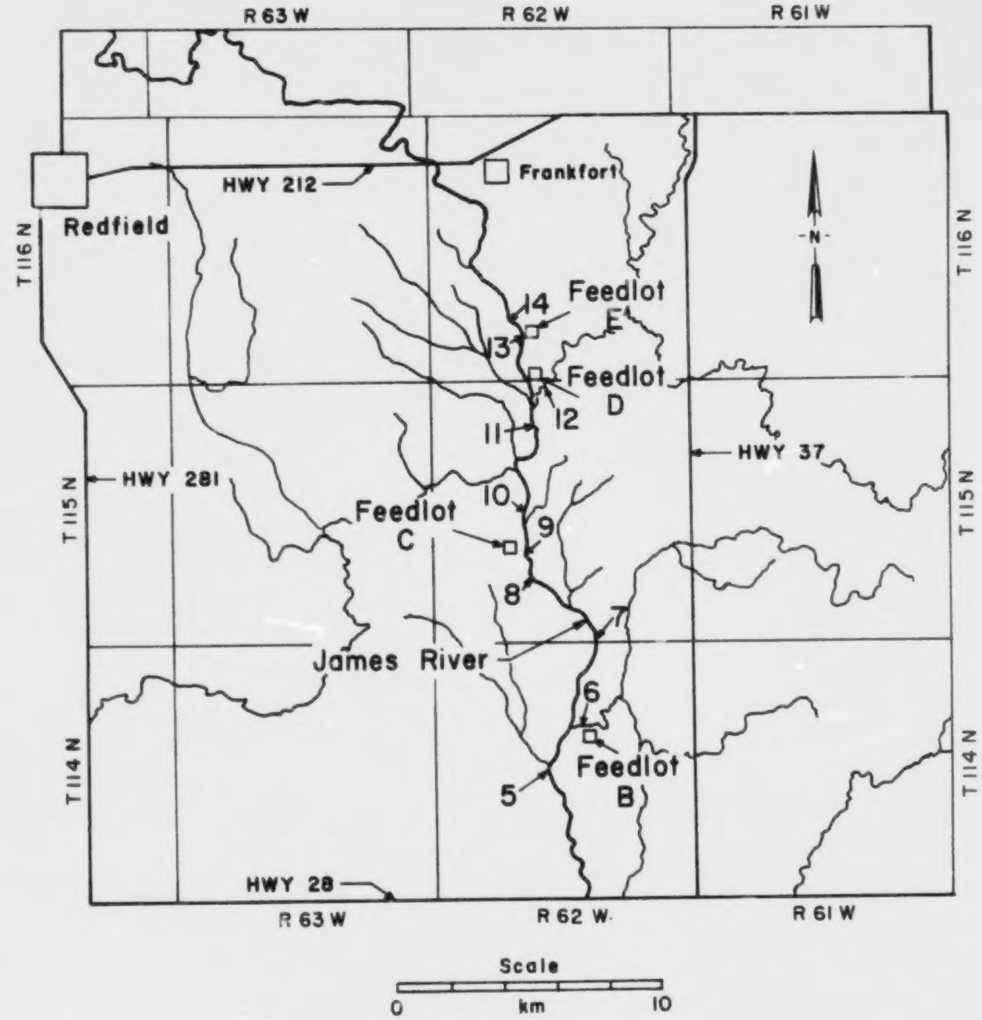

R 63 W
R 62 W
R 61 W
Frankfort
HWY 212
Redfield
T 116 N
T 116 N
N
14
Feedlot
E
13
Feedlot
D
12
11
HWY 37
HWY 281
T 115 N
T 115 N
10
Feedlot
C
9
8
7
James River
6
Feedlot
B
5
T 114 N
T 114 N
HWY 28
R 63 W
R 62 W
R 61 W
Scale
0
km
10

Figure 6. Location of feedlots and sampling sites in northern half of project area. Feedlots designated by letters and sampling sites by numbers.

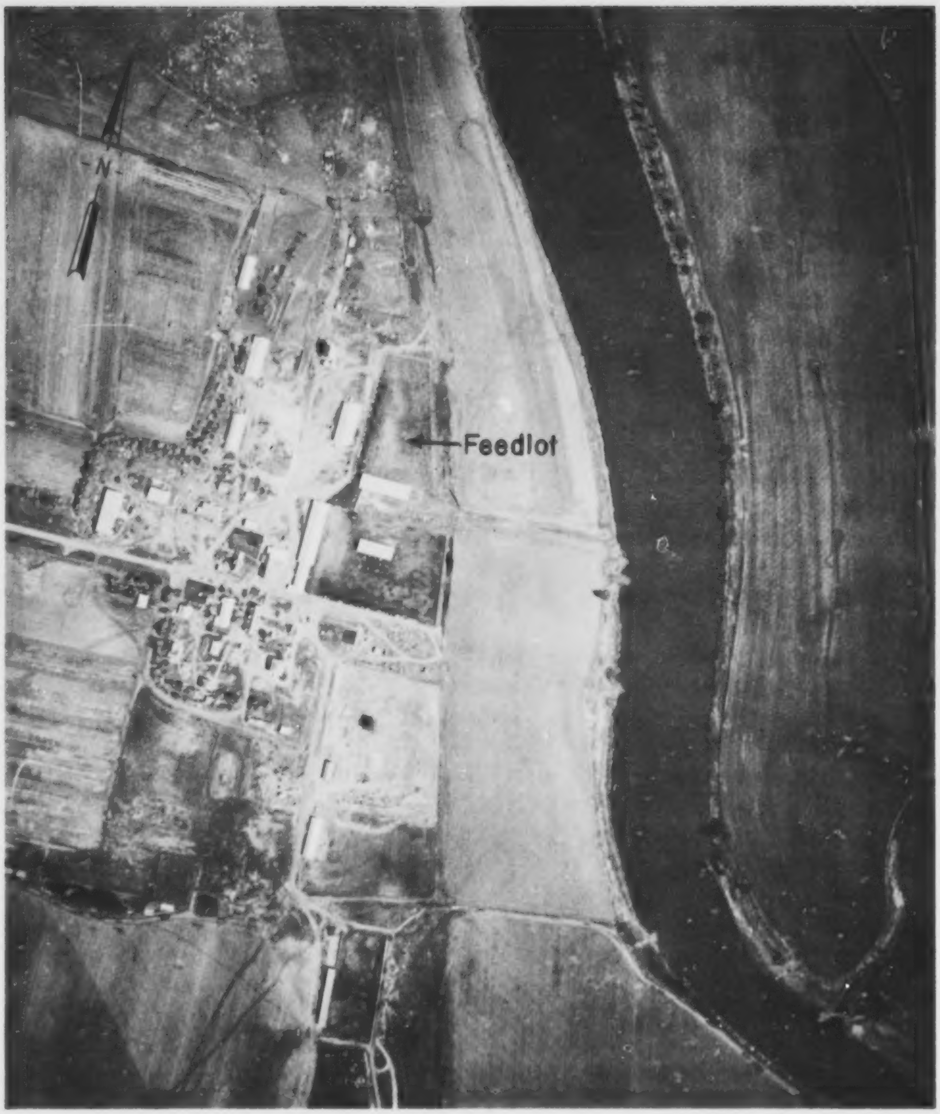


Figure 7. Feedlot site A from 70mm color film, #2448 with HF3 filter, taken May 26, 1971, 1067m agl, 3 X enlargement, scale: 1cm = 70.5m.

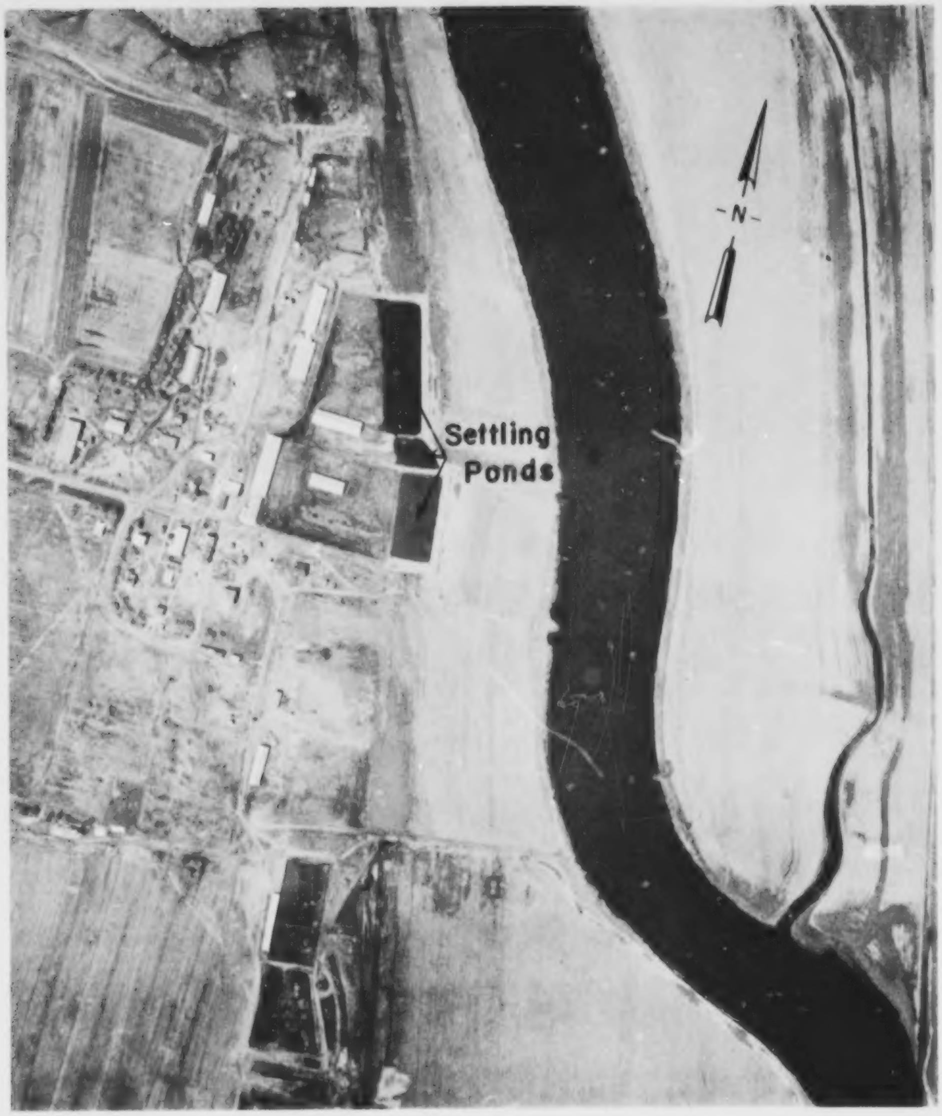

Settling
Ponds
N

Figure 8. Feedlot site A from 70mm color film, #2448 with HF3 filter, taken May 4, 1972, 1067m agl, 3 X enlargement, scale: 1cm = 70.5m.

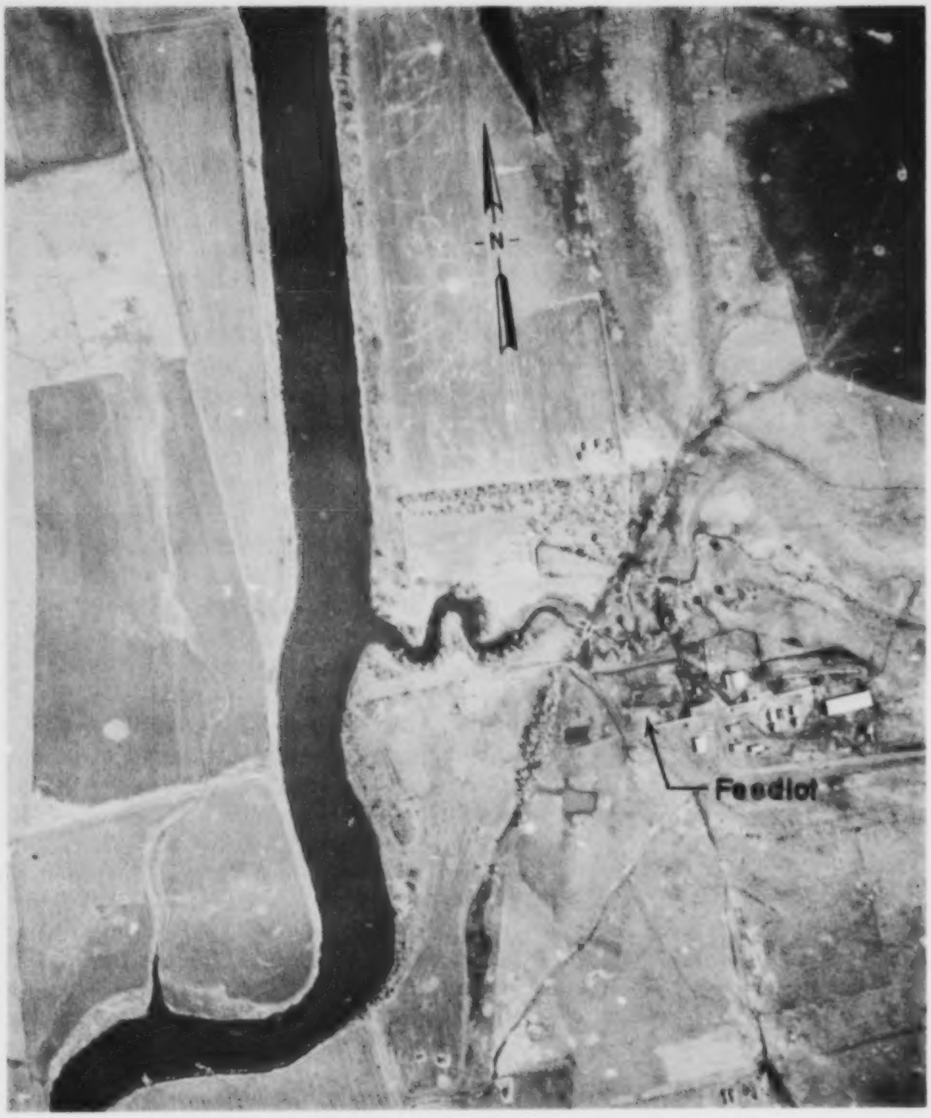


Figure 9. Feedlot site B from 70mm color film, #2448 with HF3 filter, taken April 29, 1971, 1067m agl, 3 X enlargement, scale: 1cm = 70.5m.

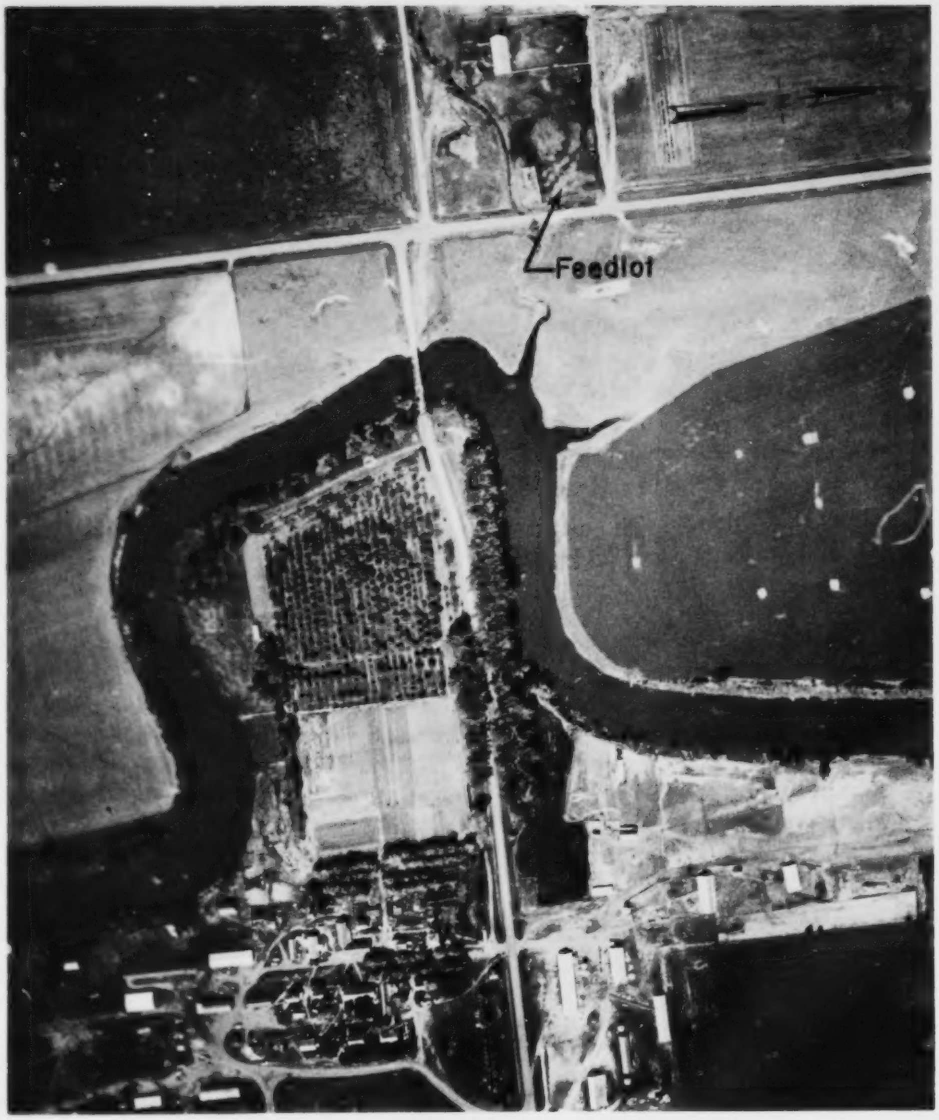


Figure 10. Feedlot site C from 70mm color film, #2448 with HF3 filter, taken May 26, 1971, 1067m agl, 3 X enlargement, scale: 1cm = 70.5m.

has been made to divert the runoff from the feedlot.

Site D, shown in Figure 11, is a 150 feeder calf unit located next to the James River and next to a stream flowing into the James River. Although runoff from the feedlot does not seem to drain directly to the river in any observable drainageway, the close proximity of the feedlot to the river makes it a potential pollution problem.

Site E, shown in Figure 12, is a relatively small beef feeding operation of 40 cows and feeder calves. Drainage from the feeding area is toward the river but, because of the relatively small size of the operation, pollution may not be a problem. The site was selected to possibly illustrate that not all feedlots are polluters, even though located near a water source.

Aerial Data Collection

Aerial data collection was conducted during all seasons of the year. Aerial missions flown during the winter were for the purpose of locating feedlots and potential pollution under snowcover conditions. Aerial missions flown in the spring, summer and fall were for detecting and monitoring the movement of feedlot pollutants to water supplies following the spring thaw and runoff-producing rainfall. Thirteen aerial missions were conducted during the project period. Table B1 in Appendix B lists the data, weather conditions, and other pertinent information for each aerial flight.

Aerial data collection was accomplished with a twin engine Beechcraft, RC45J. Weather permitting, the flight altitudes were 3050 meters (10,000 feet) above ground level over the complete flight line of 129 kilometers (80 miles) and 1067 meters (3500 feet) above ground level over the selected study areas. Sensors used to collect the aerial data included four 70 mm format, Hasselblad cameras; Daedalus thermal infrared scanner; Barnes precision radiation thermometer; and solameters. Table 1 lists the sensors, spectral ranges and film types for the project. It should be noted that not all sensors or film-filter combinations were used for each mission (see Table B1).

Aerial missions were scheduled as soon as possible after runoff-producing rainfall. Due to the unfavorable flying and aerial photographic conditions often encountered following a rainfall it was difficult to obtain timely data; therefore some aerial flights were scheduled when adverse conditions prevailed such as partial or complete cloud cover. Figure 13 is an example of a color photograph taken with partly cloudy conditions. The effect of the cloud on the amount of incoming radiation reaching the water surface and the resultant effect on the film density is evident from the photograph.

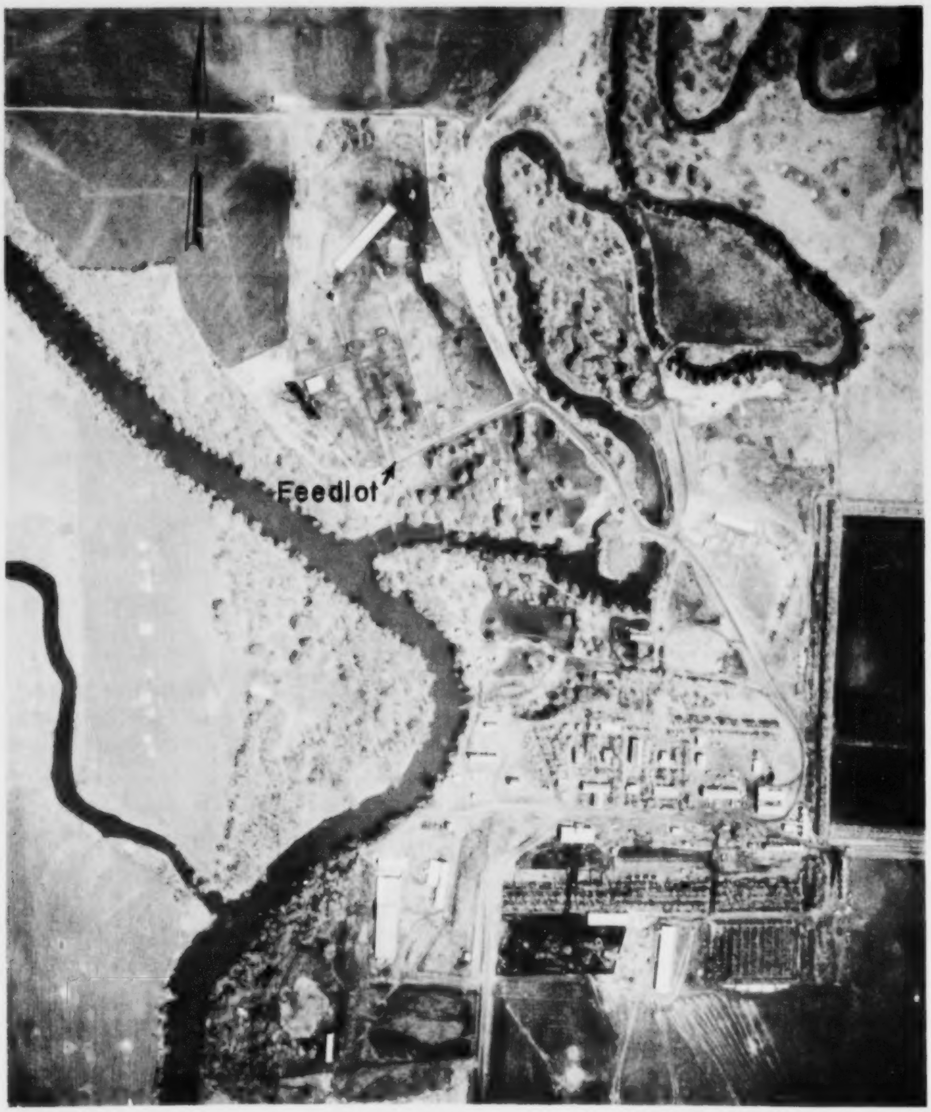


Figure 11. Feedlot site D from 70mm color film, #2448 with HF3 filter, taken April 29, 1971, 1067m agl, 3 X enlargement, scale: 1cm = 70.5m.

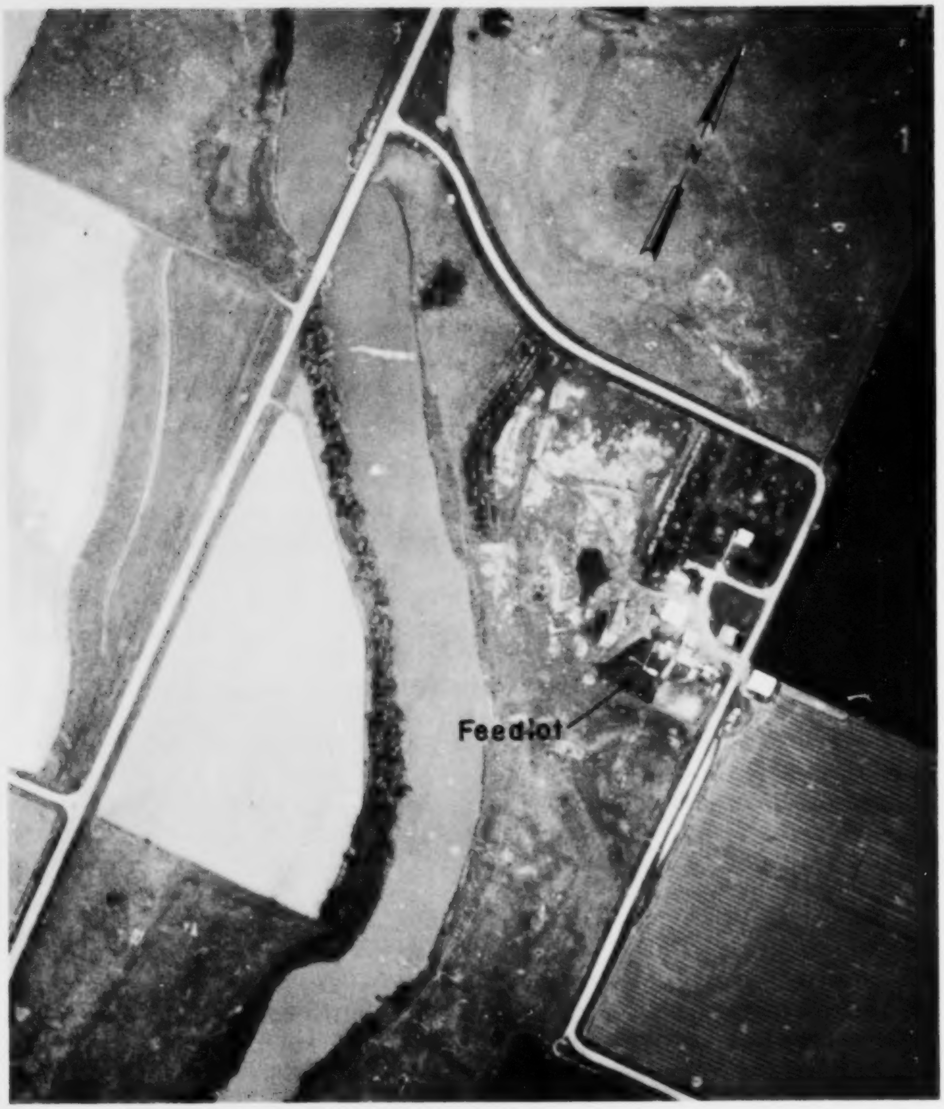


Figure 12. Feedlot site E from 70mm color film, #2448 with HF3 filter, taken June 11, 1971, 1067m agl, 4 X enlargement, scale: 1cm = 52.7m.

Table 1. REMOTE SENSING AERIAL DATA COLLECTION

Variables	Spectral Range	Method of Collection
Photography		70 mm Hasselblads
Black and White Film - Filtered		
Red - #25A	0.59μm → 0.70μm	2402 film
Green - #58	0.47μm → 0.61μm	2402 film
Blue - #47B	0.37μm → 0.50μm	2402 film
Color Film - Filtered		
Color reversal infrared - #15G + 30M	0.51μm → 0.90μm	2443 film
Color film - #HF3 + 4	0.39μm → 0.70μm	2448 film
Incoming Radiation	0.35μm → 1.15μm	Solameter
Outgoing Radiation - Filtered		Solameter
Green - #58	0.47μm → 0.61μm	
Blue - #47B	0.35μm → 0.50μm	
Thermal Infrared Radiation	4.5 μm → 5.50μm	Daedalus Line Scanner
Surface Temperature	8.0 μm →14.00μm	Barnes PRT
Haze Condition		Evaluate
Cloud Type and Condition		Evaluate
Cloud Cover (%)		Evaluate

Another problem encountered was sunglint or the reflection of direct sunlight off the surface of the water. This is also illustrated in Figure 13. To avoid this problem aerial flights were scheduled two hours before or after the sun reached its highest solar angle and cameras were tripped at an interval providing 60 percent stereo overlap. Figure 14 is an example of a color photograph taken with favorable sun angle conditions.

Ground Truth Data Collection

Ground truth data collection consisted of securing water samples at 14 sites selected to provide samples above or upstream from the feedlots, at the feedlots and below or downstream from the feedlots. Figures 5 and 6 show the location of the water sampling sites in relation to the five feedlots.

Sample site number 1 was located above the low-head dam at Huron. It was selected as a control site as it was downstream from all other sampling sites and also it is the location at which the Water Resources Division of the United States Geological Survey at Huron collects water samples for their analysis. The assumption was made that the dam did not affect the water quality of the samples taken at site number 1.

Sample sites 2, 3, and 4; 5, 6, and 7; 8, 9, and 10 were located below, at and above feedlots A, B, and C respectively. Sample sites 11 and 12 were located below and at feedlot D, and samples sites 13 and 14 were located below and above feedlot E. Due to the close proximity of feedlots D and E, sample site 13 was considered as the above sample site for feedlot D and the below sample site for feedlot E.

Water samples were collected a minimum of every three weeks from April 7 through November 3 regardless of whether an aerial mission was scheduled. The three week minimum between sample collection was used to provide a regular schedule enabling the water quality data to be analyzed independently. Table C1, Appendix C, provides sampling dates and the results of the water analysis.

When aerial data collection was made, the water samples were collected as close to the time of the overflight as possible. Samples were taken at mid-stream by lowering a one quart weighted plastic container one foot below the water surface. The water temperature at each sample site was also recorded. Samples were kept in coolers and delivered to the laboratory within six hours after collection to minimize sample deterioration.

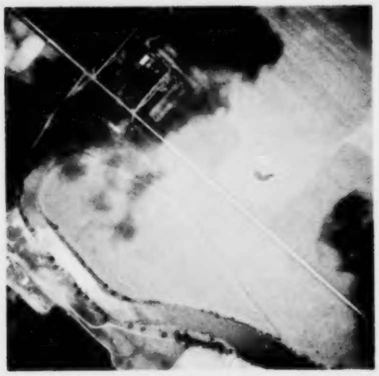


Figure 13. Print from color film #2448 with HF3 filter showing effects of cloud cover and sunglint, June 11, 1971, 1067m agl, scale: 1cm = 211m.

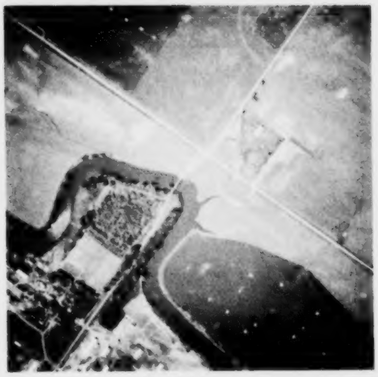


Figure 14. Print from color film #2448 with HF3 filter taken with favorable conditions on May 26, 1971, 1067m agl, scale: 1cm = 211m.

Two types of analysis were performed on the water samples -- bacteriological and analytical. The bacteriological analysis, performed by the Bacteriology Department Laboratory at South Dakota State University, determined numbers of total coliform bacteria, fecal coliform bacteria, and fecal streptococcus bacteria. The procedure used was the Most Probable Number (MPN) technique. The analytical procedure performed by the Water Resources Institute Water Quality Laboratory at South Dakota State University determined dissolved oxygen, chemical and biochemical oxygen demand, kjeldahl nitrogen, nitrates, total phosphate, total solids, total volatile solids, suspended solids, volatile suspended solids, pH, conductivity, and turbidity. All analyses were conducted according to methods outlined in the 13th edition of _Standard Methods for the Examination of Water and Wastewater_ (12). Complete results of the analyses are presented in Appendi C.

ANALYSIS AND RESULTS

Water Quality Analysis

Analysis of the water quality data, independent of the aerial data, was conducted to provide indications of trends over the complete sampling period from April 7 through November 3, 1971. Statistical analysis of variance was used with F-tests indicating which sources of variation were significant at the one and five percent levels. The analysis of variance design which was used is presented in Table 2. The sources of variation for this design consisted of the 12 water sampling dates from April 29 through November 14; feedlot sites A, B, C, and D; the above, at and below water sampling sites; and all combinations of the above. Feedlot E was not used in the analysis because water samples were collected only above and below the feedlot. Table 3 presents a summary of the results of the F-tests. The results indicate that significant differences did exist between sampling dates, feedlots and sampling sites for a number of water quality parameters. Complete results of the analysis of variance of the water quality parameters are presented in Appendix D.

Table 2. ANALYSIS OF VARIANCE OF WATER QUALITY PARAMETERS

Source of Variation	Degrees of Freedom
Dates (D)	11
Feedlots (F)	3
Sites (S)	2
DF	33
DS	22
FS	6
DFS	66
Total	143

Table D2 in Appendix D shows the average of the 14 water sampling sites for each sampling date from April 7 through November 3, 1971. Biochemical oxygen demand, chemical oxygen demand, and nitrate nitrogen were highest for the first sampling date, April 7, 1971. This is a possible indication that spring runoff caused the greatest amount of pollution during the sampling period. Biochemical oxygen demand is a common term used to indicate the concentration or pollutional strength of organic wastes in terms of the oxygen demand exerted by the waste on a body of water. It measures the quantity of free oxygen required

Table 3. SUMMARY OF SIGNIFICANCE TESTS FOR ANALYSIS OF VARIANCE OF WATER QUALITY PARAMETERS

Water Quality Parameters	Source of Variation					
	Dates	Feedlots	Sites	DF	DS	FS
Temperature	**	**			**	**
Kjeldahl Nitrogen	**	**		**		**
Biochem Oxygen Dem	**	*				**
Chem Oxygen Dem	**					
Dissolved Oxygen	**		**		*	**
Nitrate Nitrogen						**
Total Phosphates	**	**		**		**
pH	**	*	**	**	*	**
Conductivity	**			**		
Total Solids	**	*		**		
Total Vol Solids	**			*		
Susp Solids	**	*	**			*
Vol Susp Solids	**	**				
Turbidity	**	**	*			
Total Coliform						
Fecal Coliform						
Fecal Strep			*			

** Significant at the one percent level.
* Significant at the five percent level.
Blank not significant.

by bacteria for biological decomposition under aerobic conditions, at a specified temperature and a specific time period.

The means for the 14 sampling dates at each of the 14 sampling sites are presented in Table D3 of Appendix D. Sample site six showed the most variability. This could be attributed to the fact that the site was located on an intermittent stream which did not flow except under heavy runoff conditions. When the stream was not flowing, samples were taken from stagnant water backed up from the James River. Concentrations of biochemical oxygen demand, chemical oxygen demand and kjeldahl nitrogen were the lowest for site six but the concentrations of total coliform, fecal coliform and fecal streptococcus were also among the highest for site six.

Sample site 12 was a situation similar to site six as it was located on a stream flowing into the James River with the stream flowing only during periods of heavy runoff conditions. Biochemical oxygen demand and kjeldahl nitrogen were highest for site 12 and concentrations of chemical oxygen demand and nitrate nitrogen were also among the highest of the sample sites. No other sample site exhibited any marked water quality trends over the period during which samples were obtained.

Table 4 presents the South Dakota water quality standards for the James River for selected use categories and also the observed water quality at selected sampling sites. The observed water quality

Table 4. COMPARISON OF WATER QUALITY CRITERIA AND OBSERVED WATER QUALITY OF THE JAMES RIVER

	Water Quality Standards*			Observed Water Quality	
Water Quality Parameters	Domestic Water Supply	Irrigation	Intermittent Stream	Sample Site 1	Sample Site 6
Total Coliform MPH	5000	5000	20,000	549	15927
Fecal Coliform MPN		1000		159	15027
Dissolved Solids, Total ppm	1000	700 to 1500			
Suspended Solids ppm			30	30	38
pH	6.0-9.0		6.0-9.5	8.5	8.3
Nitrates, NO_3 ppm	45			0.08	0.28
Conductivity micromhos/cm @25°C		1000 to 2500		1156	1114
Biochemical Oxygen Demand, ppm			30	4.4	3.9

* Taken from "Water Quality Standards for the Surface Waters of South Dakota".

at sample site six was above the standard for total and fecal coliform and suspended solids. For sample site one, the observed water quality was equal to or less than the water quality criteria for all the water quality parameters. From Table D4 in Appendix D the total suspended solids for all but two of the sampling sites was above 30 ppm which is the water quality criteria for an intermittent stream. The water quality data collected shows that the water quality of the James River was above the acceptable standards for some of the parameters.

Film Density--Water Quality Analysis

The analysis of the film density and water quality parameter data consisted of statistical analysis of variance, linear correlation and linear regression. In addition the water quality data were correlated with adjusted film densities obtained as explained in the section on research methodology.

Film densities were measured on the 1067 m (3500 ft) altitude imagery at the location of each of the 14 water sampling sites. Because the imagery was taken with 60 percent overlap per frame, it was possible to obtain more than one film density for each sampling site. Two sets of film density data were obtained. One set consisted of taking the average of all valid film densities for each sampling site, or in other words, all densities not appearing to be affected by sunglint or cloud cover. The second set of film densities was obtained by taking the density closest to the center of the frame and not affected by sunglint or cloud cover. From the linear correlation analysis of both sets of film density data with the water quality data it was apparent there was no advantage to reading all the valid film densities and obtaining an average film density. Therefore all analyses presented in this report will utilize only the "center of the frame" film density data.

The analysis of variance using the total film densities for all four films is presented in Table 5. No attempt was made to change density values of the positive (color) and the negative (black and white) films. The sources of variation consisted of the four film-filter combinations, seven aerial flight dates, 14 sampling sites and all combinations of the above. Only seven of the nine flight dates could be used in the analysis. Results of the F-tests in Table 5 show that there was a significant difference between film densities for the flight dates, the four film-filter combinations, and the flight dates by film-filter interaction.

Table 5. ANALYSIS OF VARIANCE OF FILM DENSITIES

Sources of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F
Films (F)	3	22.25	7.42	247.5**
Dates (D)	6	1.15	0.19	6.3**
Sites (S)	13	0.42	0.03	1.0
FD	18	14.17	0.79	27.4**
FS	39	0.90	0.02	0.7
DS	78	0.96	0.01	0.3
FDS	234	7.80	0.03	
Total	391	47.66		

** Significant at the one percent level.

The analysis of variance of film densities for color and color infrared film is presented in Table 6. The source of variation consisted of the two film-filter combinations (color and color infrared),

Table 6. ANALYSIS OF VARIANCE OF COLOR AND COLOR INFRARED FILM DENSITIES

Sources of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F
Films (C)	1	41.29	41.285	13,760**
Filters (F)	3	50.63	16.876	5,630**
Dates (D)	6	30.94	5.157	1,720**
Sites (S)	13	3.57	0.274	90**
CF	3	15.38	5.126	1,710**
CD	6	10.03	1.671	556**
CS	13	1.22	0.093	30**
FD	18	2.76	0.153	50**
FS	39	0.14	0.004	1
DS	78	18.28	0.234	77**
CFD	18	2.86	0.159	53**
CFS	39	0.16	0.004	1
CDS	78	5.15	0.066	23**
FDS	234	0.63	0.003	1
CFDS	234	0.80	0.003	
Total	783	183.83		

** Significant at the one percent level.

the four densitometer filters (total, red, green and blue), seven aerial flight dates, fourteen sampling sites and all combinations of the above. Results of the F-tests indicate a significant difference existed between film densities for film types, densitometer filters, aerial flight dates, and sampling sites. The source of variance between films, filters and the associated interactions may be exaggerated due to the difference in response of the two color films (i.e. color IR is a false color film).

The comparison between film densities and the water quality parameter analysis was accomplished with the statistical method of linear correlation. Correlation coefficients were computed for each of the nine aerial flights and for all of the aerial missions combined. The correlation coefficients were tested for significance different from zero at the five and one percent levels. Table 7 presents the correlation coefficients for film densities versus water quality parameters for the nine aerial missions combined making a total of 126 observations. The significance from zero is shown by * for the .05 level and ** for the .01 level. Significant correlation coefficients were obtained for temperature, dissolved oxygen, suspended solids, turbidity and total coliform for most of the film-filter combinations. The highest correlation coefficients were obtained for the black and white film with green filter #58. Figure 15 is a plot of the correlation coefficients versus aerial flight dates for the black and white film with the green filter #58. This film-filter combination is presented because of the higher correlation coefficients obtained in the analysis. Suspended solids, turbidity, temperature and dissolved oxygen are plotted on the graph. Considerable variability between aerial flights can be noted from the graph. Correlations for suspended solids, turbidity, and dissolved oxygen were significantly different from zero for one mission date while correlations for temperature were significant for four aerial missions.

Figure 16 is a plot of correlation coefficients versus aerial flight dates for the infrared sensitive layer of the color infrared film. Considerable variability between aerial flights is again evident for this film-filter combination. The complete correlation analysis for each aerial mission is presented in Table D4 of Appendix D.

Linear regression equations computed for the film densities and water quality parameters are presented in Table D5 of Appendix D. The dependent variable is water quality and the independent variable is film density. Comparison of the standard errors of the regression coefficients indicate the variation of the estimated coefficient. The regression equations for the green layer of the color infrared film showed the smallest standard error for most of the water quality parameters.

Table 7. CORRELATION COEFFICIENTS FOR FILM DENSITIES AND WATER QUALITY PARAMETERS FOR NINE DATA COLLECTION MISSIONS

Water Quality Parameters	B&W Green Filter #58[1]	B&W Blue Filter #47B[1]	Color IR Total	Color IR Infrared Sensitive Layer	Color IR Red Sensitive Layer
Temperature	.735**	-.259**	-.407**	-.492**	-.376**
Kjeldahl Nitrogen	.076	.065	-.167	-.037	-.158
Biochem Oxygen Dem	-.093	-.160	-.054	.136	-.086
Chem Oxygen Dem	-.148	.233**	-.024	.013	-.022
Dissolved Oxygen	-.500**	.194	.328**	.410**	.300**
Nitrate-Nitrogen	-.054	.092	-.006	-.098	.000
Total Phosphates	.047	-.294**	.055	.058	.050
pH	-.236**	.141	.356**	.270**	.345**
Conductivity	.204**	-.305**	-.090	-.153	-.069
Total Solids	.103	-.275**	-.109	-.115	-.087
Total Vol Solids	.040	-.201**	-.062	-.114	-.050
Susp Solids	.323**	-.006	-.224*	-.298**	-.209*
Vol Susp Solids	.304**	.053	-.230**	-.264**	-.225*
Turbidity	.541**	-.109	-.324**	-.484**	-.301**
Total Coliform	-.330**	-.196**	.333**	.175	.390**
Fecal Coliform	-.027	-.125	.016	-.045	.023
Fecal Strep	-.190	-.122	.170	.074	.207*

Table 7. Continued

Water Quality Parameters	Color IR Green Sensitive Layer	Color Total	Color Red Layer	Color Green Layer	Color Blue Layer
Temperature	-.338**	-.276**	-.368**	-.239*	-.206*
Kjeldahl Nitrogen	-.130	.143	.151	.122	.024
Biochem Oxygen Dem	-.061	.086	.096	.058	.040
Chem Oxygen Dem	-.019	.014	.072	-.015	-.096
Dissolved Oxygen	.256**	.250**	.311**	.204*	.155
Nitrate Nitrogen	.044	-.161	-.162	-.162	-.196*
Total Phosphates	.100	.099	.049	.116	.071
pH	.338**	-.099	-.020	-.141	-.195*
Conductivity	-.071	-.001	-.046	.030	.108
Total Solids	-.100	.165	.115	.203*	.252**
Total Vol Solids	-.027	.019	-.011	.029	.001
Susp Solids	-.188*	-.262**	-.277**	-.255*	-.235*
Vol Susp Solids	-.198*	-.281**	-.287**	-.287**	-.211*
Turbidity	-.254**	-.425**	-.465**	-.404**	-.349**
Total Coliform	.357**	.267**	.275**	.258**	.204*
Fecal Coliform	.074	-.049	-.060	-.048	-.054
Fecal Strep	.194	.129	.122	.128	.098

* Significantly different from zero at the five percent level.

** Significantly different from zero at the one percent level.

[1] Correlations for the negative type black and white films have opposite signs from the positive type color films.

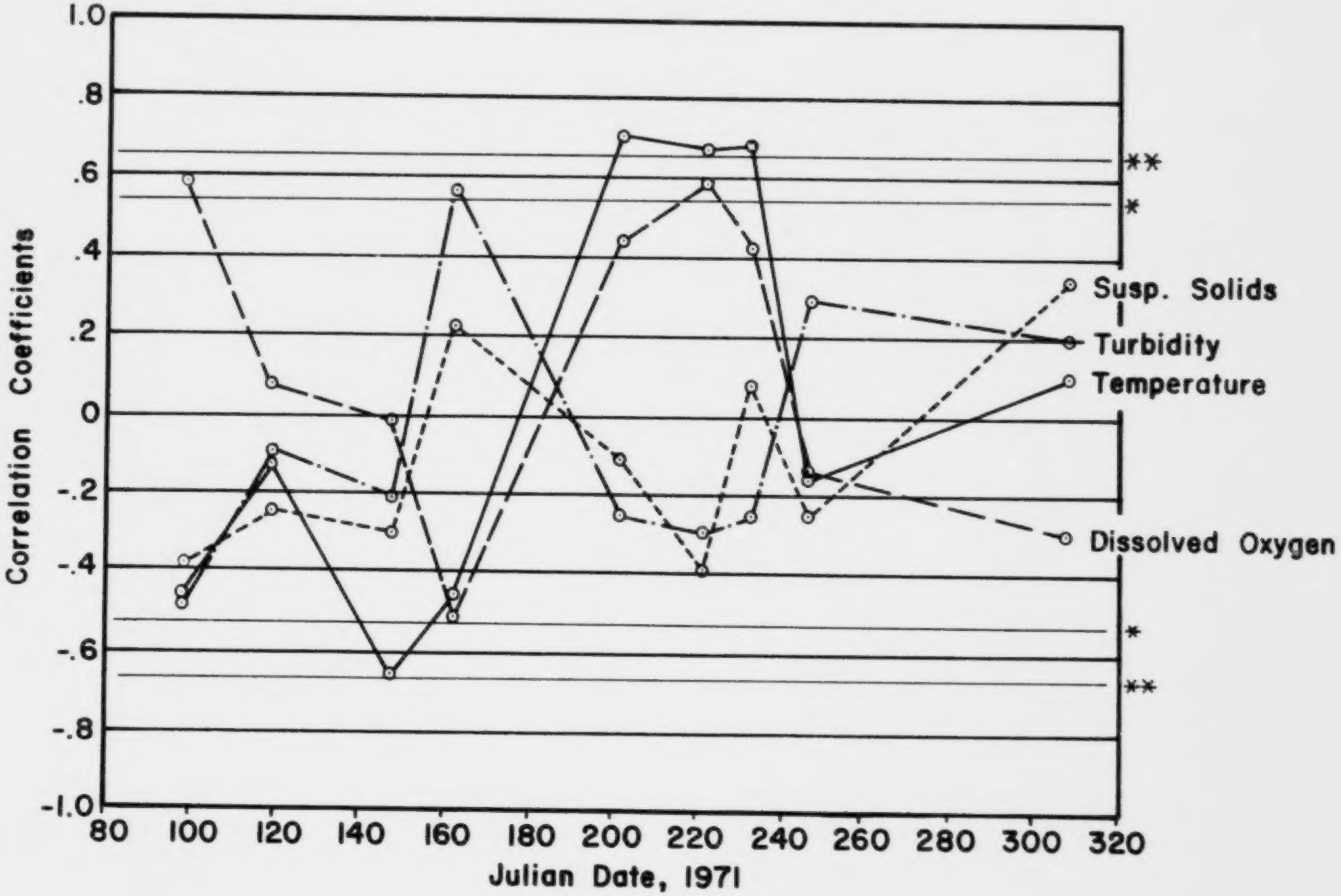


Figure 15. Mission correlation coefficients plotted against time for the black and white film with green filter, #58.

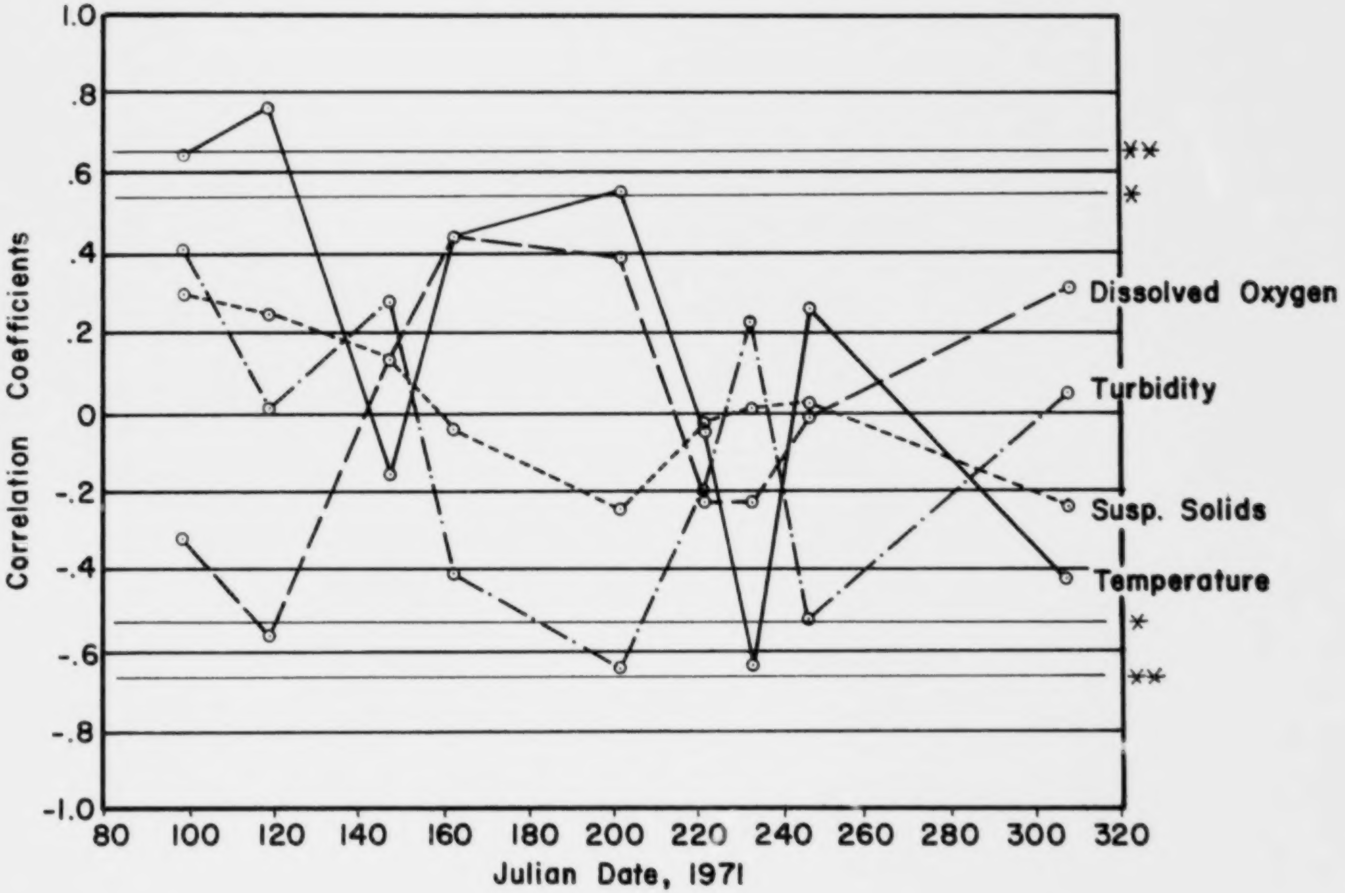


Figure 16. Mission correlation coefficients plotted against time for the color infrared film, #2443, with a red densitometer filter.

To relate film density and water quality, variables other than water quality need to be considered. One of these variables is incoming radiation. Film densities were adjusted for variations in incoming radiation by the method outlined in the section on Research Methodology. The water quality parameters were then correlated with the adjusted film densities as with the regular film densities. The results of the correlation of the adjusted film densities versus the water quality parameters for the nine aerial flights combined are presented in Table 8.

For most of the water quality parameters the correlation coefficients for the adjusted film densities were lower than for the uncorrected film densities. Conductivity and total solids are two exceptions of interest. Conductivity correlates with the black and white films with a green and blue filter and with the color infrared film higher than with uncorrected density correlations. The same was true for total solids except for the black and white film with a blue filter. The complete correlation analysis for adjusted film densities for each aerial mission is presented in Table D6 of Appendix D.

The variability and, in most cases, lower correlation coefficients obtained for the adjusted film densities can be attributed to the fact that the camera speed and aperature settings were not kept constant during and between aerial missions. The setting of camera speed and aperature is essentially an adjustment for incoming radiation and therefore the technique used for film density adjustment most likely resulted in over compensation for incoming radiation.

Thermal Imagery Analysis

Water temperature is an important parameter because of its effect on the aquatic life, dissolved oxygen content, and chemical and biological reactions of a body of water. The temperature of a river may be changed in a number of ways such as discharging of warm water from a thermal or nuclear fueled electric power generating plant, removing irrigation water from a stream and returning warmer drainage water, changing shade conditions along the river by removing trees and by the entrance of water from underground streams and aquifers into the river. Feedlots could alter the temperature of a river by discharging warmer water and nutrients which increase the potential of algae growths in the river. The ability of water to hold oxygen is reduced by higher temperatures because oxygen is less soluble in warm water than cold water. Oxygen also combines more rapidly with organic wastes as the water temperature increases. Thus oxygen may be consumed more rapidly than it can be replaced as the water flows downstream.

From the thermal infrared imagery collected during this project no temperature anomalies due to feedlot runoff were observed other

Table 8. CORRELATION COEFFICIENTS FOR ADJUSTED FILM DENSITIES AND WATER QUALITY PARAMETERS FOR NINE DATA COLLECTION MISSIONS

Water Quality Parameters	B&W Green Filter #58[1]	B&W Blue Filter #47B[1]	Color IR Total	Color IR Infrared Sensitive Layer	Color IR Red Sensitive Layer
Temperature	-.495**	.350**	-.213*	-.123	-.217*
Kjeldahl Nitrogen	.103	.002	.045	.185*	.003
Biochem Oxygen Dem	.238**	-.045	.179*	.352**	.101
Chem Oxygen Dem	.314**	-.121	.141	.169	.118
Dissolved Oxygen	.374**	-.273**	.225*	.144	.222*
Nitrate-Nitrogen	.025	-.087	-.033	-.113	-.031
Total Phosphates	-.082	.332**	.123	.088	.104
pH	.235**	-.197	.276**	.029	.299**
Conductivity	-.330**	.199*	-.233**	-.271**	-.187*
Total Solids	-.250**	.159	-.250**	-.218*	-.208*
Total Vol Solids	-.142	.148	-.150	-.189	-.122
Susp Solids	-.151	.048	-.162	-.128	-.158
Vol Susp Solids	-.111	.026	-.123	-.053	-.136
Turbidity	-.386**	.130	-.304**	-.307**	-.286**
Total Coliform	.415**	.105	.098	-.085	.185
Fecal Coliform	.058	.193	.064	.007	.062
Fecal Strep	.098	.012	-.031	-.149	.024

Table 8. Continued

Water Quality Parameters	Color IR Green Sensitive Layer	Color Total	Color Red Layer	Color Green Layer	Color Blue Layer
Temperature	-.207*	-.311**	-.389**	-.283**	-.233*
Kjeldahl Nitrogen	.009	.032	.027	.021	-.079
Biochem Oxygen Dem	.103	.048	.052	.026	-.001
Chem Oxygen Dem	.097	.000	.063	-.031	-.119
Dissolved Oxygen	.186*	.196*	.239*	.166	.098
Nitrate Nitrogen	.046	-.141	-.134	-.149	-.173
Total Phosphates	.168	.080	.032	.099	.058
pH	.298**	-.111	-.034	-.147	-.210*
Conductivity	-.161	-.181	.233*	-.142	-.048
Total Solids	-.195*	-.006	-.069	.047	.109
Total Vol Solids	-.072	-.080	-.115	-.055	-.086
Susp Solids	-.148	-.235*	-.244*	-.227*	-.202*
Vol Susp Solids	-.128	-.235*	-.232*	-.243*	-.166
Turbidity	-.232**	-.394**	-.418**	-.376**	-.314**
Total Coliform	.203*	.052	.035	.065	.015
Fecal Coliform	.111	-.021	-.024	-.028	-.024
Fecal Strep	.061	-.039	-.058	-.028	-.040

* Significantly different from zero at the five percent level.

** Significantly different from zero at the one percent level.

[1] Correlations for the negative type black and white films have opposite signs from the positive type color films.

than Figure 21 which was recorded with ice conditions on the river. The linear correlation of thermal infrared densities with the water quality parameters also did not produce estimates significantly different from zero as is evident from Table 9. Only four of the nine aerial missions were used for the correlation analysis because of equipment adjustments made during the other flights thereby causing variations in the resultant film densities. The lack of significant correlation between the thermogram densities and the actual temperatures measured on the ground may be due to the time differential between the aerial overflight and the temperature measurement and to sampling error.

Some examples of temperature variations that were observed are presented to illustrate the capability of thermal infrared techniques. Figure 17 is a thermal infrared print of an area of the James River recorded on August 19, 1971. Light shades are warmer than dark shades. Point X is a control dam where the water temperature is warmer above the dam than just below the dam due to the constant mixing of the water as it flows over the spillway. Another phenomenon noticeable from the print is the gradual cooling trend in the river from the dam to point Y. At this point the area of the river next to the triangular field (Point Z) exhibits a warmer temperature for which no explanation is available.

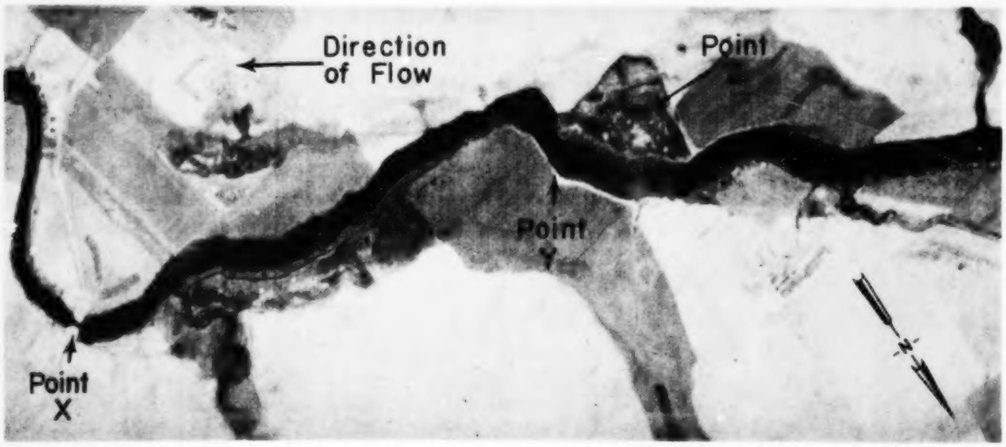


Figure 17. Thermal infrared print showing a section of the James River scanned on August 19, 1971, 1067 m agl, scale: 1 cm = 500 m.

Table 9. CORRELATION COEFFICIENTS FOR THERMAL INFRARED FILM DENSITIES AND WATER QUALITY PARAMETERS FOR FOUR AERIAL MISSIONS

Water Quality Parameters	June 11, 1971	July 20, 1971	August 9, 1971	August 19, 1971
Temperature	.208	.108	.305	.353
Kjeldahl Nitrogen	.153	.013	-.509	-.147
Biochem Oxygen Dem	.352	.048	-.355	.289
Chem Oxygen Dem	.330	-.079	-.162	.235
Dissolved Oxygen	.442	-.264	.357	.500
Nitrate Nitrogen	.044	.377	.104	-.085
Total Phosphates	.226	-.291	-.293	.119
pH	.256	-.052	.581*	-.075
Conductivity	.153	.140	.537*	-.360
Total Solids	.231	.183	.431	-.475
Total Vol Solids	.064	.147	.524	.327
Susp Solids	-.224	.366	-.084	.088
Vol Susp Solids	-.095	.478	.076	.153
Turbidity	-.480	.604*	-.066	-.143
Total Coliform	.409	.242	.414	.088
Fecal Coliform	.214	.343	.424	.090
Fecal Strep	.166	-.105	-.195	.074

* Significantly different from zero at the five percent level.

Visual Analysis

One objective of this project was to investigate the applicability of remote sensing techniques for locating potential feedlot pollution sources. To accomplish this objective aerial flights were scheduled during periods of snow and ice conditions when feedlots are easily discernible due to snow compaction and waste deposits by the livestock. It was found that following periods of thawing the movement of runoff from feedlots onto the ice of rivers and streams was easily detected on aerial photographs. These areas were particularly evident during the spring thaw before the breakup of the ice in the river.

The aerial mission flown on March 8, 1972, illustrated very well the potential of remote sensing for locating feedlot pollution. Figure 18 is an aerial photograph of a 40 cow dairy operation located next to the James River. Figures 19 and 20 are ground photographs of the feedlot area showing the runoff draining directly into the river. No attempt has been made to divert the runoff or correct the pollution situation to date.

Figure 21 is an aerial photograph of feedlot site A taken on March 8, 1972. As mentioned previously, settling ponds were constructed in August, 1971, to collect the runoff from the feedlot of the 200 cow dairy operation. The settling ponds are pointed out in the photograph. It appears from the photograph that runoff is still reaching the river possibly from another operation on the farm. Figure 22 is a print from a thermal scan obtained at the same time as

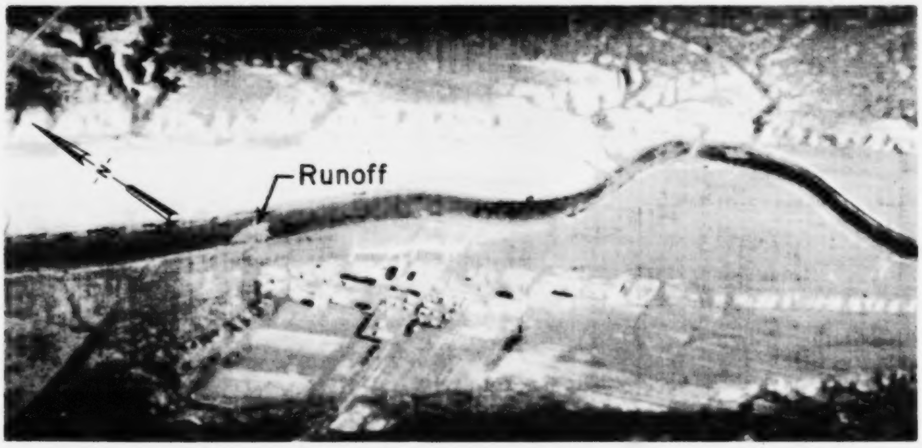


Figure 22. Print from thermal scan showing feedlot site A on March 18, 1972, 1067 m agl, scale: 1 cm = 169 m.

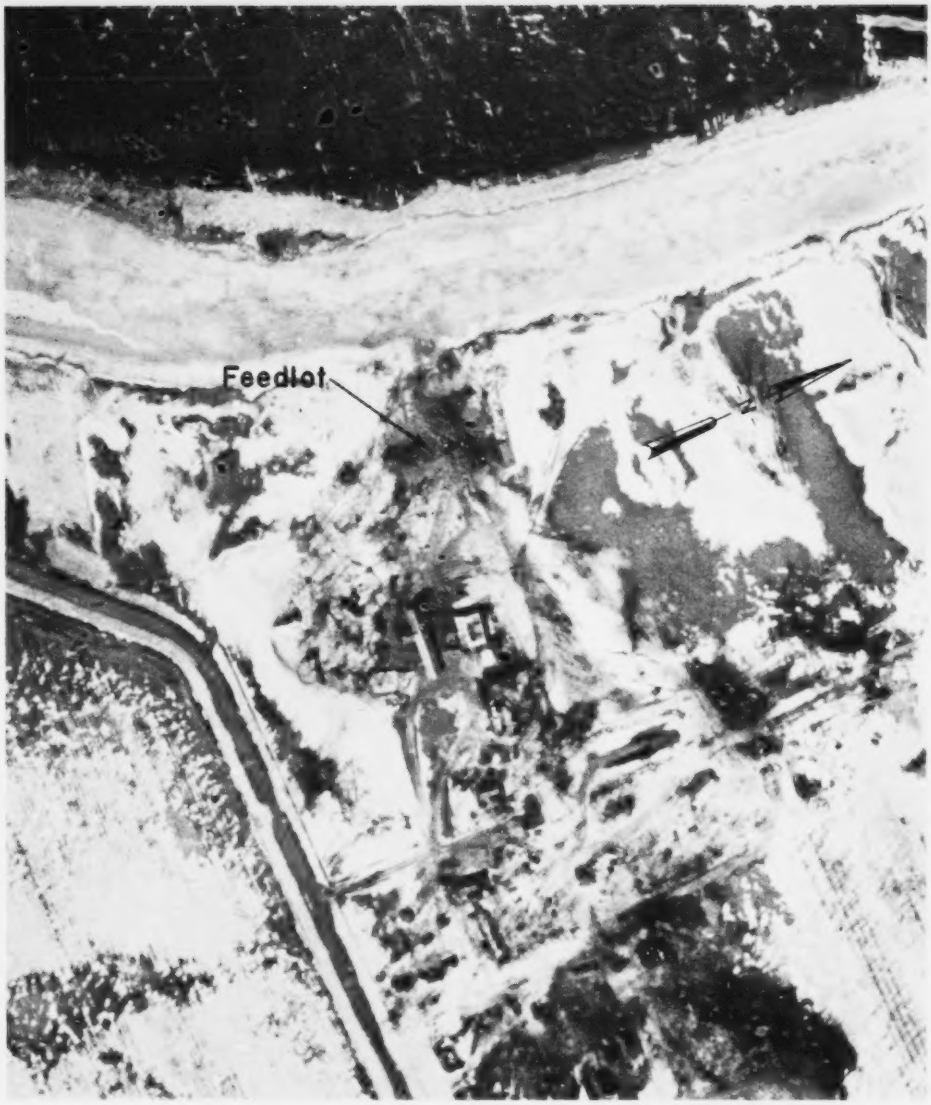


Figure 18. Print from 70mm color film, #2448 with HF3 filter, taken March 8, 1972, 1067m agl, 3 X enlargement, scale: 1cm = 70.5m.

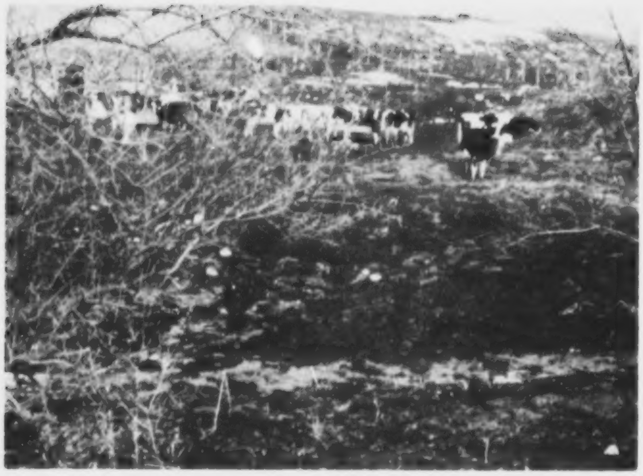


Figure 19. Ground truth photograph of feedlot shown in Figure 18, March 13, 1972.

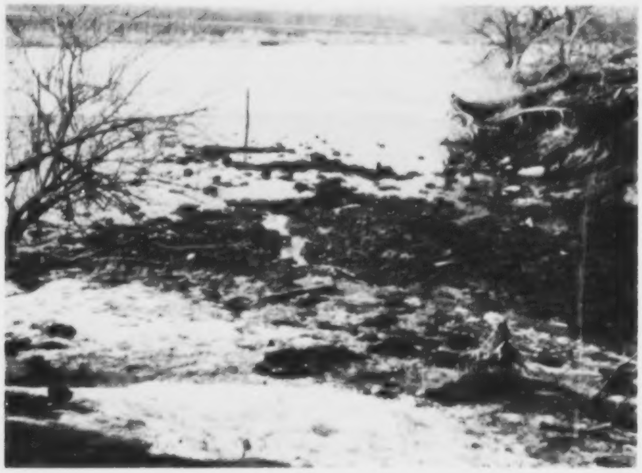


Figure 20. Ground truth photograph of feedlot shown in Figure 18, March 13, 1972.

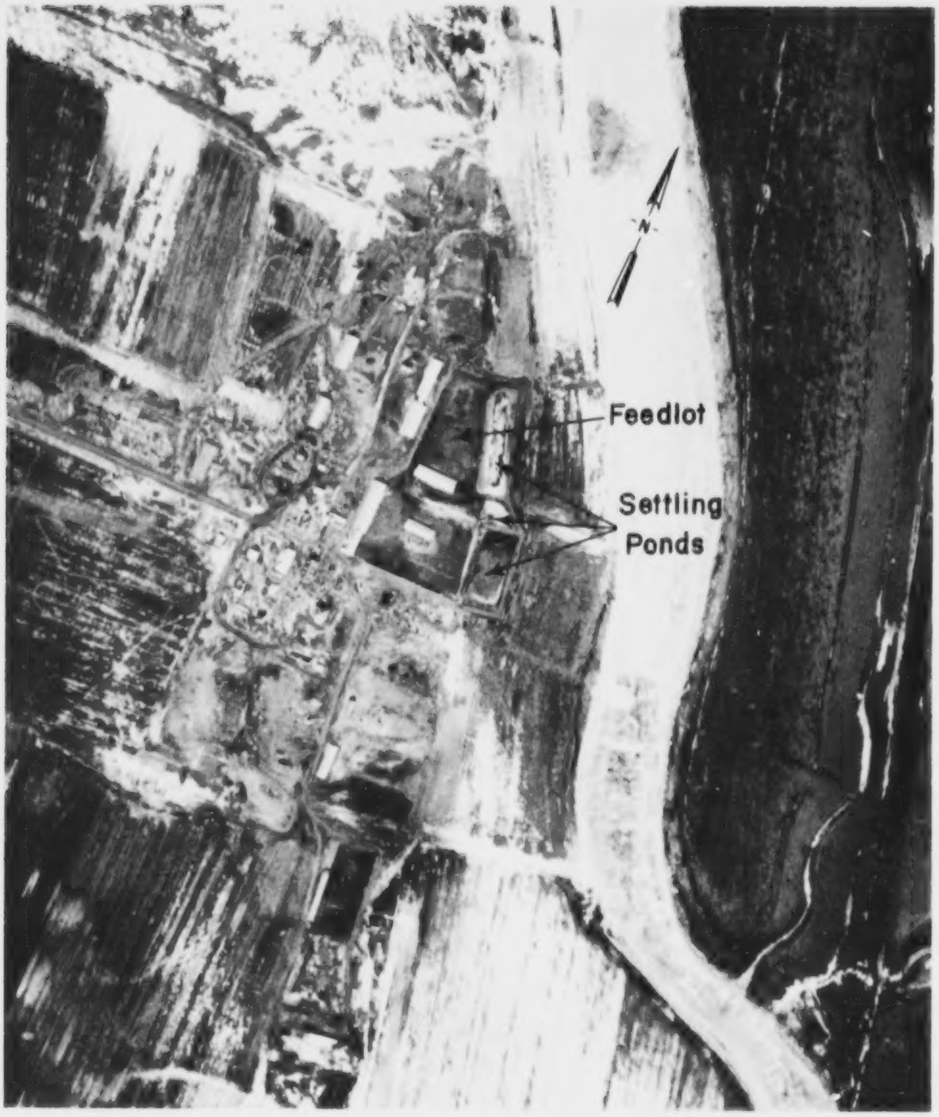

N
Feedlot
Settling
Ponds

Figure 21. Print from 70mm color film, #2448 with HF3 filter, taken March 8, 1972, 1067m agl, 3 X enlargement, scale: 1cm = 70.5m.

the aerial photograph in Figure 21. The runoff on the ice, which shows up clearly on the aerial photograph, is also evident on the thermal scan print indicating the temperature change caused by the runoff onto the ice. The ground photographs in Figures 23 and 24 show the source and effect of the runoff onto the James River.

Figure 25 is an aerial photograph of another feeding operation located on the banks of the James River. The area pointed out on the river ice may not be caused entirely by runoff from the feeding area. Looking at Figures 26 and 27 taken on the ground the potential for runoff from the feedlot reaching the river certainly does exist.

Figure 28 is an aerial photograph of feedlot site C. Examination of the aerial photograph does not reveal any runoff reaching the river at the time of the flight. However, the ground photographs in Figures 29 and 30 taken five days after the aerial flight show that runoff from the feedlot does flow directly to the James River and that a definite pollution problem does exist. This illustrates the necessity for very timely data collection during the spring thaw period.

Figure 31 is an aerial photograph of feedlot site D. Here again runoff from the feedlot onto the ice of the river is not evident at the time of the flight but because of the location of the feedlot the potential for runoff reaching the river does exist. Figure 32 is a ground photograph showing the condition of the feedlot following a period of warm weather. Figure 33 is a ground photograph of the stream running adjacent to the feedlot and into the James River.

High altitude aircraft imagery deserves consideration for use in locating potential feedlot pollution sources. Figure 34 is a print from National Aeronautics and Space Administration Mission #146 flown at 18,300 meters (60,000 feet) above ground level on November 5, 1970. High altitude photography is advantageous because of its coverage capabilities. Figure 35 is a 19X enlargement of feedlot number 1 pointed out in Figure 34. Even with the acuity lost by the enlarging process the feedlot is easy to discern from the photograph. It is interesting to note that the feedlot of Figure 35 is the same one shown in Figure 18 which was found to have a definite pollution problem. The NASA high altitude photograph indicates the potential of the feedlot as a pollution source because of its close proximity to the James River. Feedlots 2, 3, and 4 in Figure 34 do not appear to present a pollution hazard because of the distance of the feedlots from the James River. Observation on the ground would be essential to confirm or discount any suspicions developed from the high altitude aerial photographs.

Figure 36 is another print from NASA Mission #146 illustrating the use of high altitude photography for locating potential feedlot

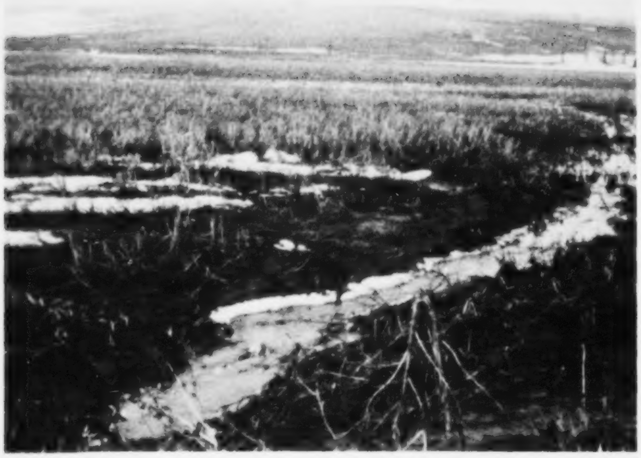


Figure 23. Ground truth photograph of area shown in Figure 21, March 13, 1972.

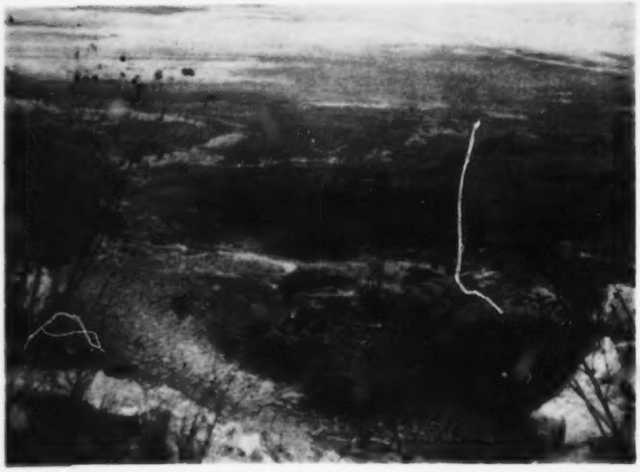


Figure 24. Ground truth photograph of area shown in Figure 21, March 13, 1972.

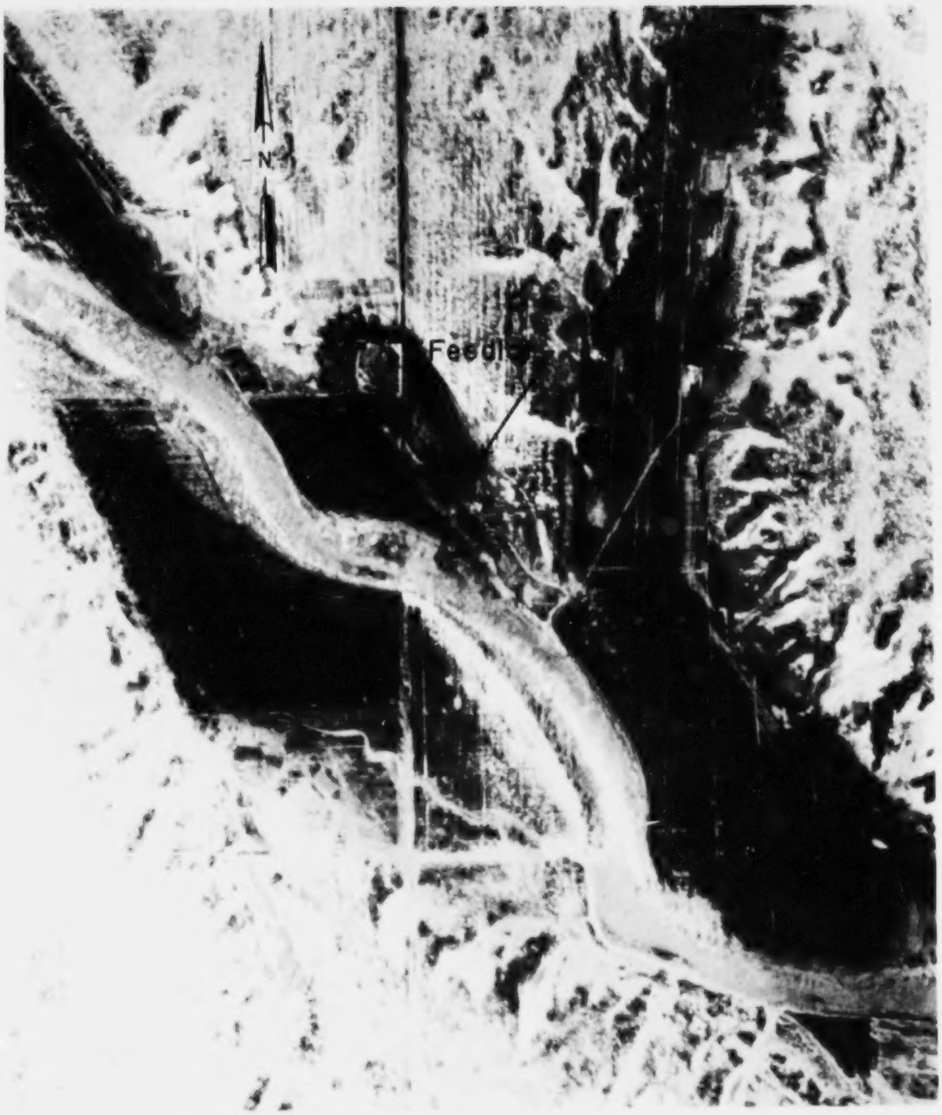


Figure 25. Print from 70mm color film, #2448 with HF3 filter, taken March 8, 1972, 1067m agl, 5 X enlargement, scale: 1cm = 42.2m.

Figure 26. Ground truth photograph of area shown in Figure 25, March 13, 1972.

Figure 27. Ground truth photograph of area shown in Figure 25, March 13, 1972.

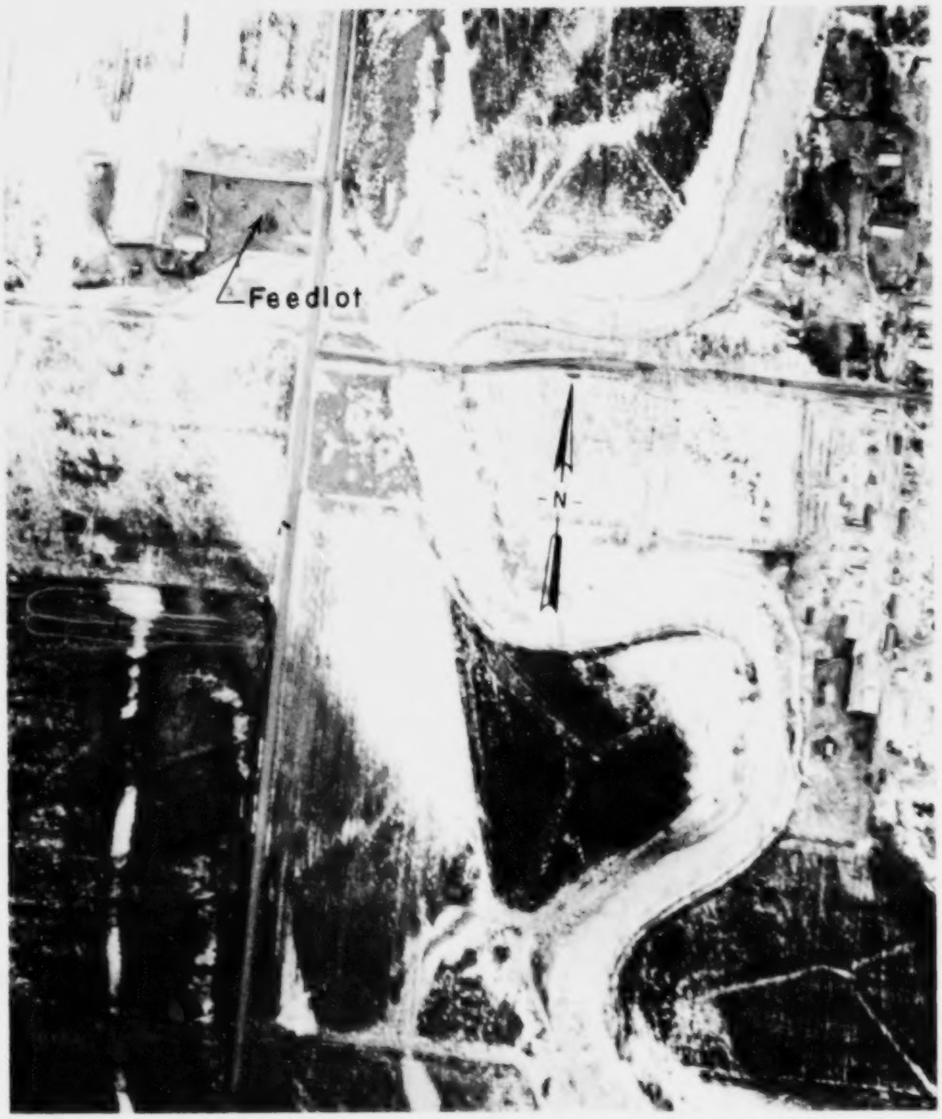


Figure 28. Print from 70mm color film, #2448 with HF3 filter, taken March 8, 1972, 1067m agl, 3 X enlargement, scale: 1cm = 70.5m.

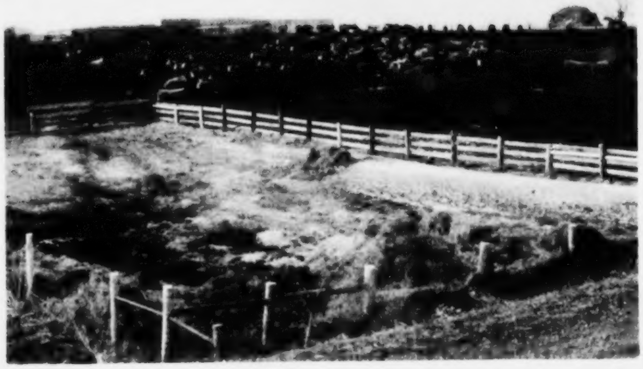


Figure 29. Ground truth photograph of feedlot shown in Figure 28, March 13, 1972.

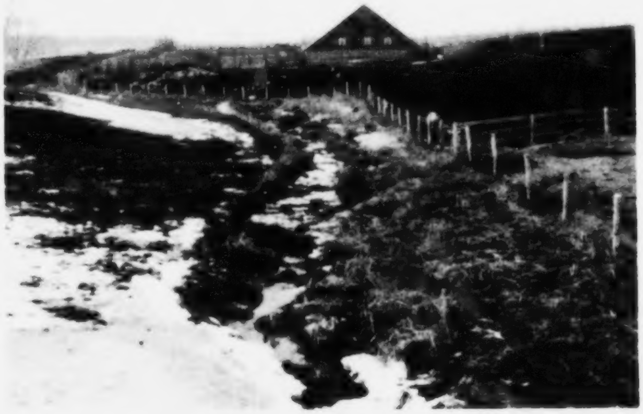


Figure 30. Ground truth photograph of feedlot shown in Figure 28, March 13, 1972.

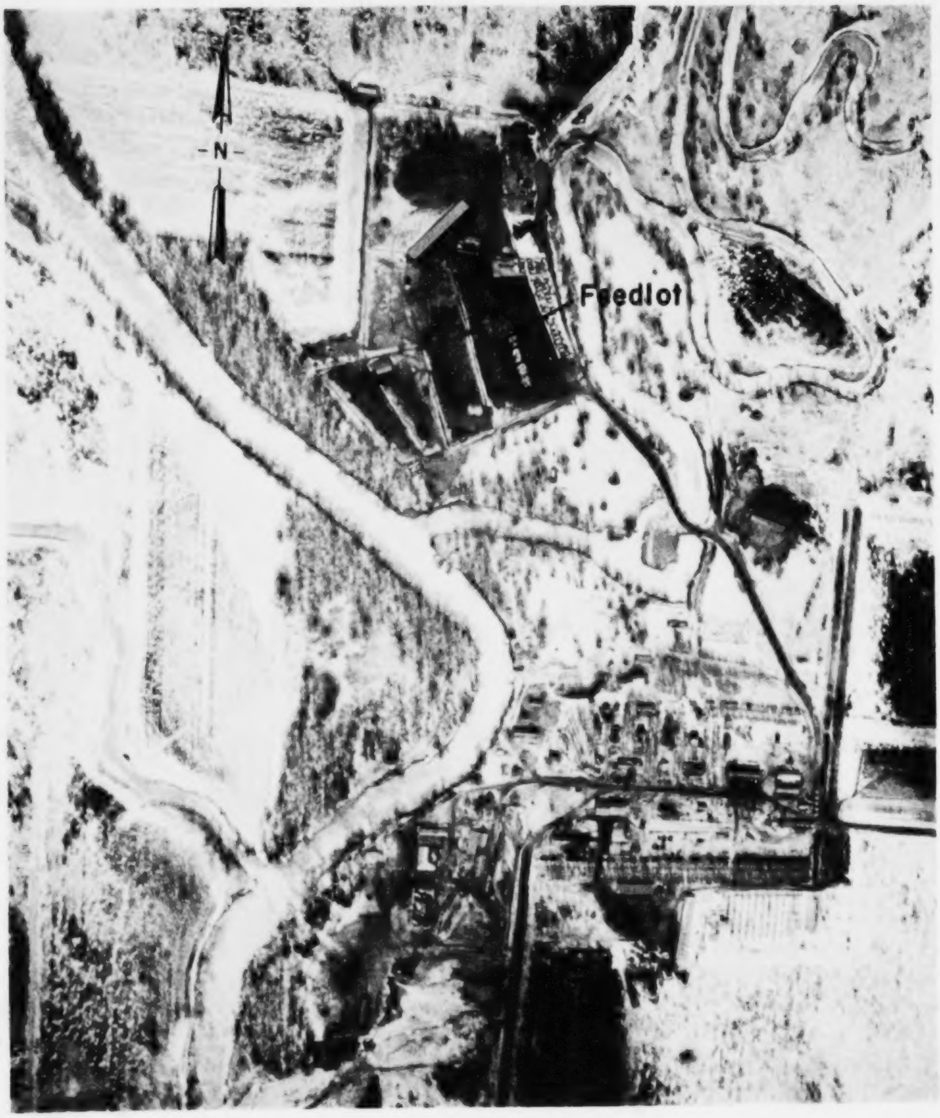


Figure 31. Print from 70mm color film, #2448 with HF3 filter, taken March 8, 1972, 1067m agl, 4.3X enlargement, scale: 1cm = 49m.

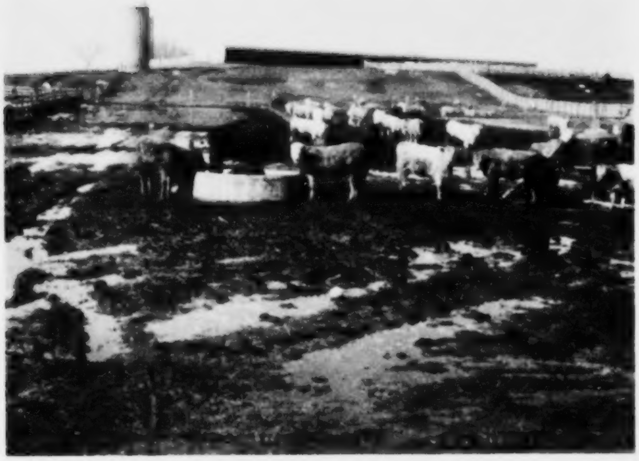


Figure 32. Ground truth photograph of feedlot shown in Figure 31, March 13, 1972.

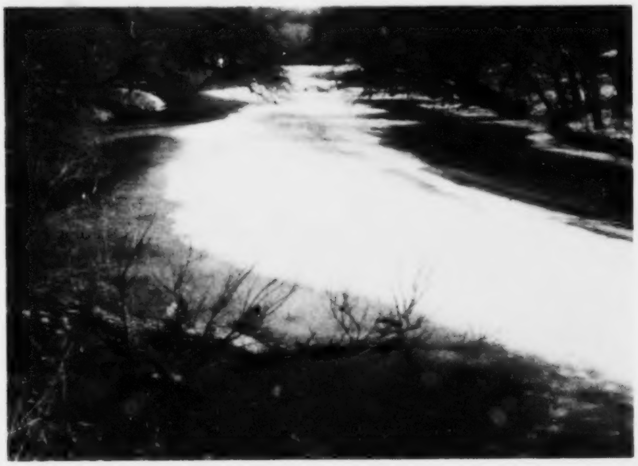


Figure 33. Ground truth photograph of stream flowing into James River located next to feedlot shown in Figure 31, March 13, 1972.

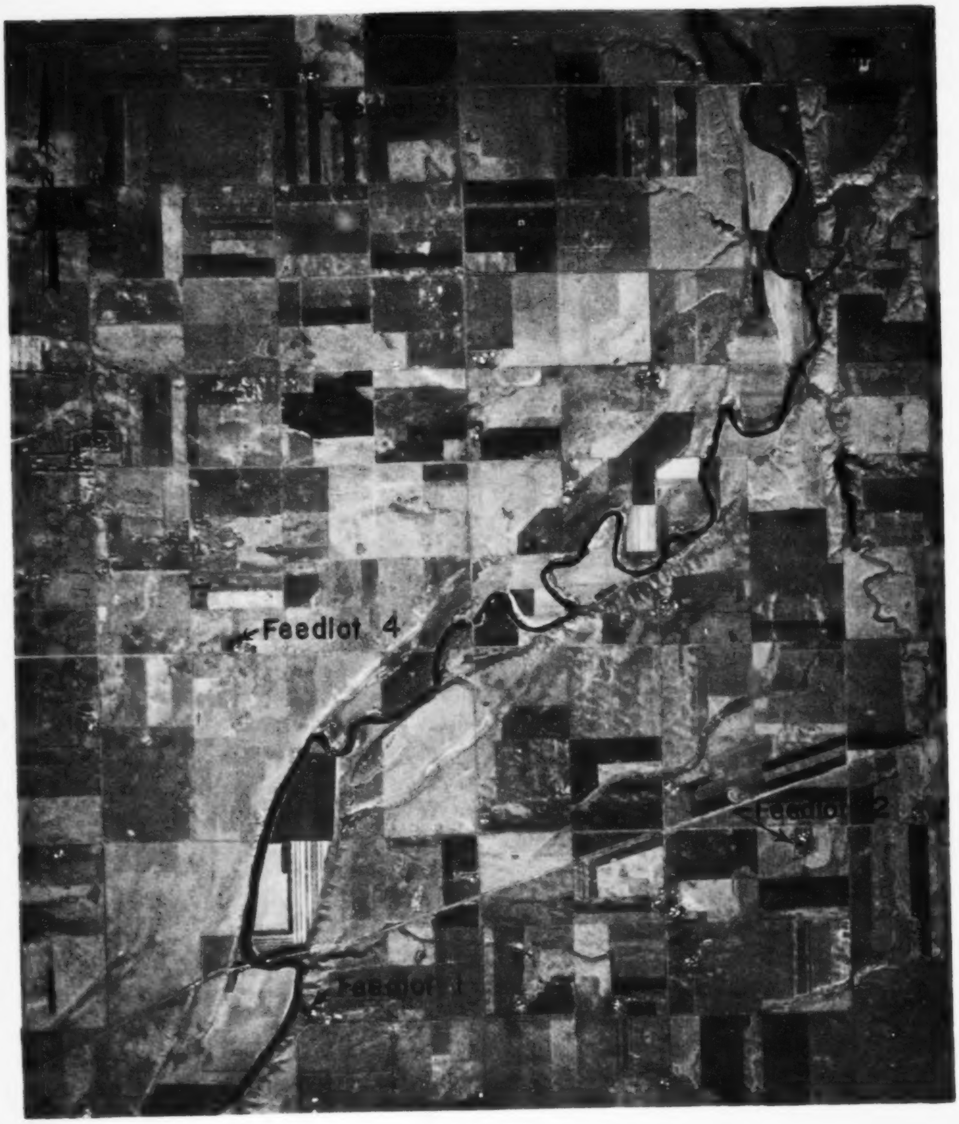

Feedlot 3
Feedlot 4
Feedlot 2
Feedlot 1

Figure 34. Print from NASA RB-57 Mission #46 taken on November 5, 1970, with color infrared film #2443, 18,300m (60,000 ft) agl, 1 X enlargement.

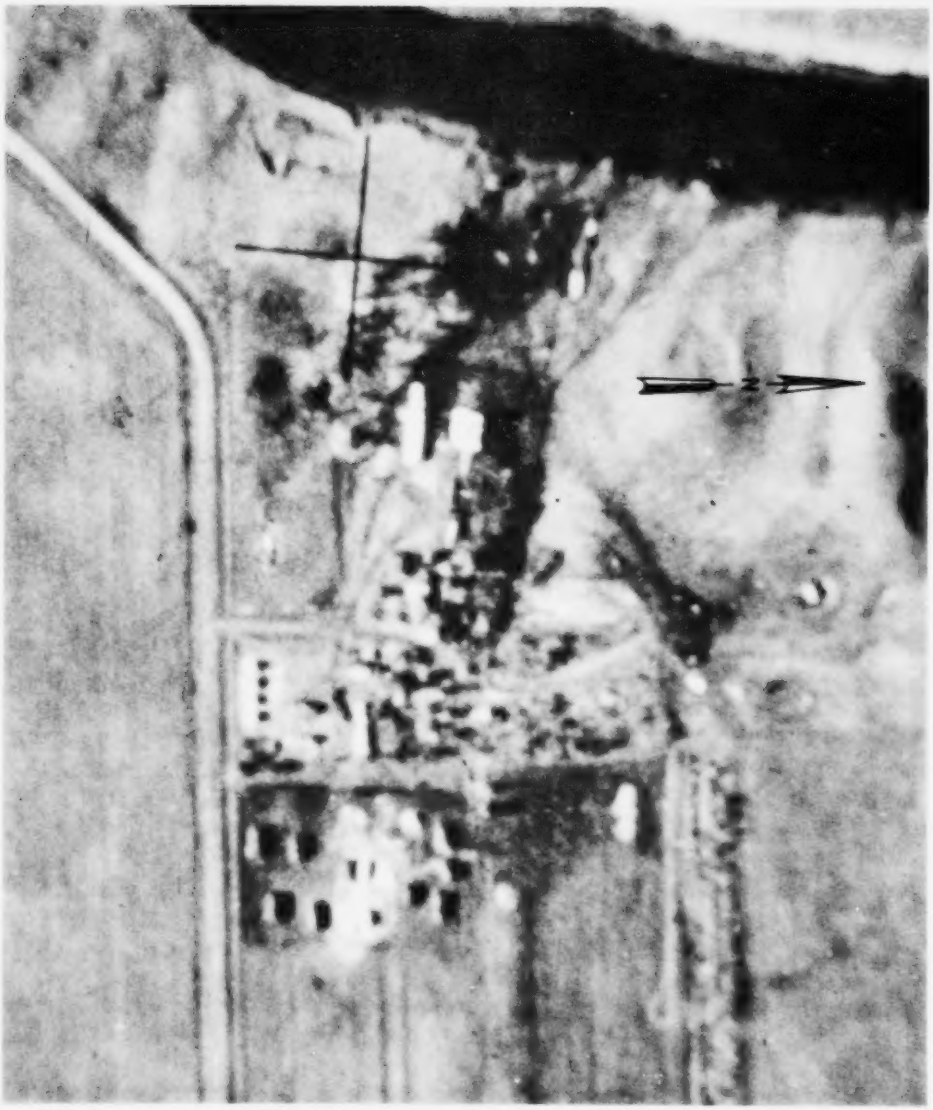


Figure 35. Print from NASA RB-57 Mission #146 taken on November 5, 1970, with color infrared film #2443, showing feedlot 1 from Figure 34, 18,300m (60,000 ft) agl, 19 X enlargement.

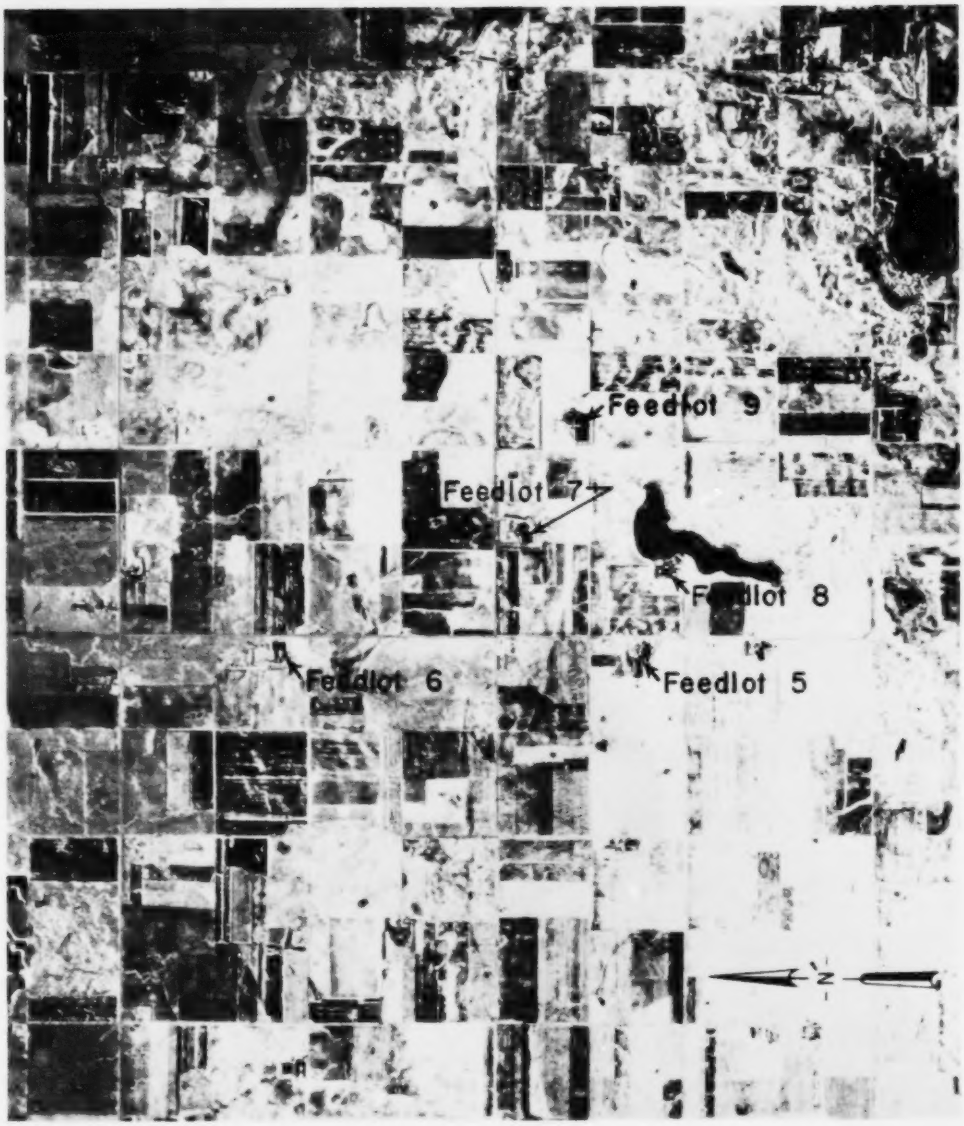

Feedlot 9
Feedlot 7
Feedlot 8
Feedlot 6
Feedlot 5
N

Figure 36. Print from NASA RB-57 Mission #146 taken on November 5, 1970, with color infrared film #2443, 18,300m (60,000 ft) agl, 1 X enlargement.

pollution sources. The partial snow cover conditions make it easier to locate the feedlots against the white surrounding terrain. Feedlots 5, 6, 7, 8 and 9 in Figure 36 are examples of feedlots which are easy to detect and locate on the aerial photograph. Feedlots 5, 6, 7 and 9 do not appear to present a pollution hazard but feedlot 8 located next to a body of water may be a potential hazard. Figure 37 is a 16X enlargement of feedlot number 9. The sharp contrast between the snow covered areas and the feedlot area makes it possible to determine the actual size and layout of the feedlot.

The examples shown in this section have illustrated the potential of timely aerial photography for locating feedlot pollution sources. It is evident that, once the potential pollution sources are located, observation of the sites on the ground is required. Aerial photography does eliminate the need for time consuming ground surveys of feedlots because not all of them present a pollution hazard. It should be pointed out that visual interpretation discussed in this section can be accomplished with a light table using inexperienced photo interpreters.

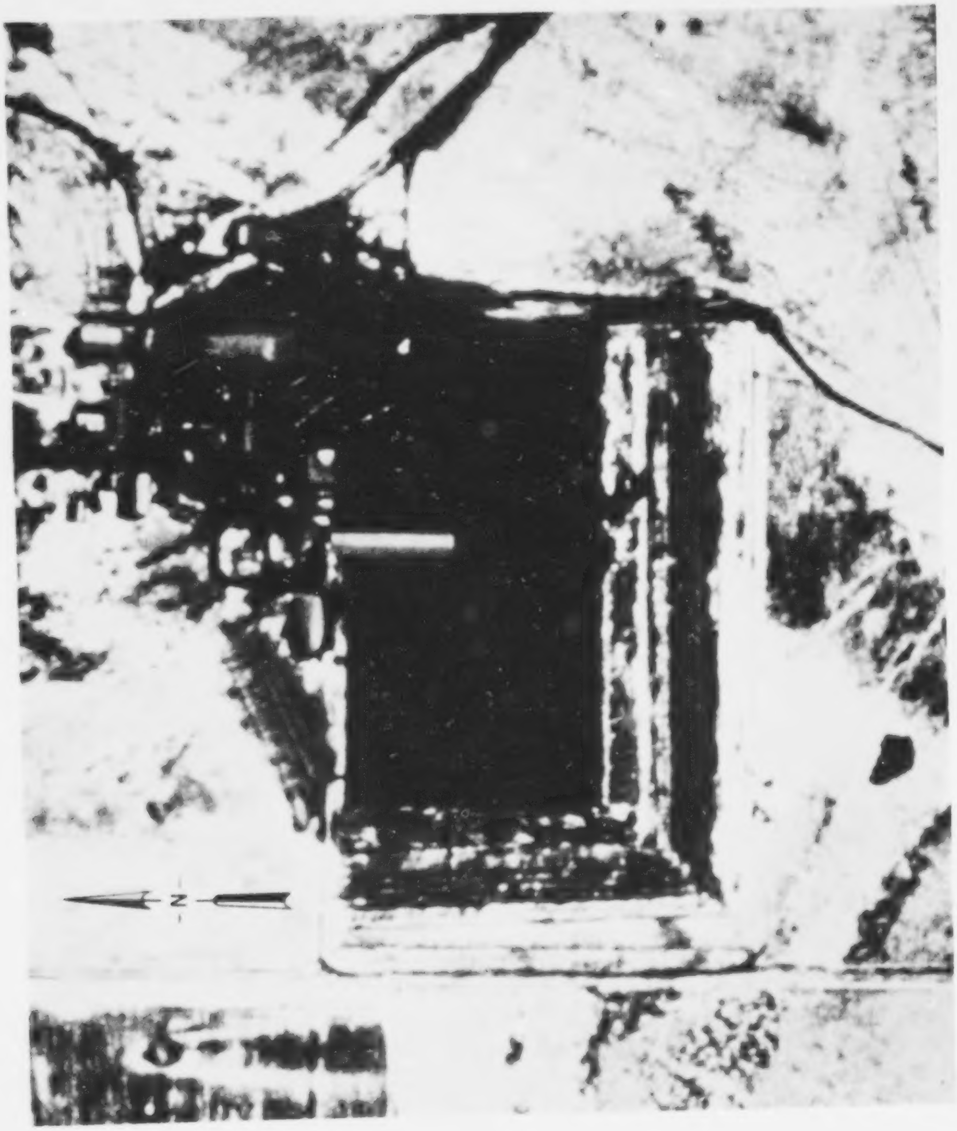


Figure 37. Print from NASA RB-57 Mission #146 taken on November 5, 1970, with color infrared film #2443, showing feedlot 9 from Figure 36, 18,300m (60,000 ft) agl, 16 X enlargement.

CONCLUSIONS AND RECOMMENDATIONS

Remote sensing techniques can be used to locate potential feedlot pollution sources and monitor the movement of the pollution to water supplies. Visual interpretation of aerial photography and thermal infrared imagery conclusively illustrated its usefulness in delineating potential pollution sources, providing that the imagery was taken at the right time with the proper conditions. The best results were obtained when aerial flights were made with ice and snow cover conditions following a period of thawing causing runoff from the feedlots. The period during the spring thaw before the breakup of the river ice was found to be an ideal time to obtain imagery showing pollution conditions. High altitude (18,300 m) photography was also found to be applicable for locating feedlots and therefore potential pollution sources.

The statistical analysis of variance of the water quality parameters and film densities revealed that significant differences were present in the data. The linear correlation analysis of film densities versus the water quality parameters showed good results for specific aerial missions but considerable variability was noted between missions. The correlation coefficients for the black and white film with a green filter showed the best results for the nine aerial missions combined. Significant correlation coefficients were obtained for temperature, suspended solids, and turbidity.

The variance in correlation coefficients obtained between aerial missions can be attributed to several factors. Variations in wind conditions from one flight date to another from one location on the river to another for the same day would cause varying wave action on the river and therefore affect the reflected radiation. The time of day and season of the year causes variations in the amount of reflected radiation. Varying cloud and haze conditions cause the attenuation of incoming radiation and therefore vary the amount of reflected radiation. The instability of photographic films and changes in film processing from one data collection to another affect the resultant film densities.

A possible cause for the lack of significant correlation coefficients is the below normal amount of snow and rainfall during the project period. This was particularly evident during the spring thaw period in 1971. The gradual melting of the limited snow cover resulted in very little runoff from the feedlots in the study area.

The attempt to adjust film density for variations in incoming radiation did not produce significant results. This was attributed to the changing of camera speed and aperature settings during and between aerial missions. Because of the need for timely data collections, aerial missions were flown with adverse conditions such as partial or complete cloud cover. Therefore, the adjustment of the camera exposure settings for existing light conditions was essential to obtain usable photographic imagery. Additional research in this area resulting in a correction for camera change could very possibily improve results.

Recommendations For Further Study

The results of this study have shown that remote sensing techniques can be used to locate potential feedlot pollution sources. The fact that significant correlation coefficients for film density versus water quality were obtained for specific data collection missions indicates that further study is warranted. Due to the lack of significant runoff events during the sampling period and the difficulty in scheduling aerial flights during or immediately after runoff, additional study may provide more consistent and conclusive results.

The results of this study indicate that the application of remote sensing techniques to an operational program of locating and monitoring feedlot pollutants seems feasible. The use of aerial photography to differentiate between feedlots presenting a pollution hazard and those not presenting a hazard would result in a considerable savings of time because detailed ground surveys of all feedlots would not be needed.

Because of the rapid advancements in remote sensing technology, new and improved data analysis equipment is continually being developed. The SADE (Signal Analysis and Dissemination Equipment) system recently installed at the Remote Sensing Institute could provide improved results. The system, which is interfaced with the University Computer Center, is capable of digitization and computer analysis of film transparencies and magnetic tape data. In addition level slicing and color encoding of film densities is possible. With the digitization capability and a direct link with the computer, data can be analyzed and decisions made in a short period of time.

The use of additional data collection equipment may also provide improved results. Automatic water sampling equipment would aid in obtaining timely water samples. A digital rainfall recorder and a digital stage recorder used in conjunction with automatic sampling equipment would provide an indication of water quality during specific portions of the runoff hydrograph. This information would aid in the interpretation of the actual amount of pollution and runoff entering the river prior to, as well as during, the aerial flight.

A spectrophotometer used in the laboratory would establish characteristic curves or "fingerprints" for the water samples collected from the river. An airborne spectrometer would make a direct measurement of the intensity of radiant energy reflected from the water surface. Processing equipment on-board the aircraft or on the ground could immediately establish the identity of the material once the characteristic reflectance, emittance, or absorption curve of the material is established.

REFERENCES

1. "Animal Waste Management", Proceedings of National Symposium on Animal Waste Management, The Airlie House, Warrenton, Virginia, 256 p., September 28-30.

2. "Climatological Data", U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Data Service, Asheville, North Carolina, Vol. 76, No. 1-12.

3. "Climatological Summary", U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Data Service, Asheville, North Carolina, 1971.

4. Electromagnetic Spectrum, Chart MB-1937, Westinghouse Electric Corporation, Printing Division, Trafford, Pennsylvania, 1961.

5. Feinstein, David L., and Piech, Kenneth R., "A Light Transport Problem in Water Pollution," Reprinted from the Proceedings of the Conference of the Institute of Environmental Sciences, Boston, April, 1970.

6. Gates, David M., "Characteristics of Soil and Vegetated Surfaces to Reflected and Emitted Radiation", Proceedings of the Third Symposium on Remote Sensing of Environment, University of Michigan, Ann Arbor, Michigan, pp. 573-600, 1966.

7. Helgeson, Gaylord A., and Ross, Donald S., "Remote Sensor Imaging for Oceanography," Oceanology, Vol. 5, No. 9, pp. 20-25, September, 1970.

8. Loehr, Raymond C., "Pollution Implications of Animal Wastes - A Forward Oriented Review", U.S. Department of Interior, Federal Water Pollution Control Administration, Robert S. Kerr Water Research Center, Ada, Oklahoma, 1968, 175 p.

9. Ross, Donald S., "Enhanced Oceanographic Imagery", Proceedings of the Sixth International Symposium on Remote Sensing of Environment, University of Michigan, Ann Arbor, Michigan, pp. 1029-1044, 1969.

10. Ryerson, Robert A., and Wood, Harold A., "The Air Photo Analysis of Beef and Dairy Farming", Photogrammetric Engineering, Vol. 37, No. 2, pp. 157-169, February, 1971.

11. Scherz, James P., and Boyle, William C., "Photographic Characteristics of Water Pollution", Instruments and Control Systems, Vol. 42, pp. 118-120, November, 1969.

12. *Standard Methods for the Examination of Water and Wastewater*, 13th Ed. New York: American Public Health Assoc., Am. Water Works Assoc., and Water Pollution Control Federation, 1971.

13. Steele, Robert G. D., and Torrie, James H., *Principles and Procedures of Statistics*, McGraw-Hill Book Company, Inc., New York, NY, pp. 183-193, 453, 1960.

14. Werner, Hal D., and Schmer, F. A., "Application of Remote Sensing Techniques to Monitoring Soil Moisture", Remote Sensing Institute Interim Technical Report, RSI-71-4, Brookings, SD, 1971.

PUBLICATIONS

1. Schmer, F. A., and Ryland, D. W., "Remote Sensing Possible Inputs to a Regulatory Monitoring System", Paper No. 71-922. Presented at the 1971 Winter Meeting of the American Society of Agricultural Engineers, Chicago, Illinois, December 7-10, 1971.

2. Schmer, F. A., Ryland, D. W., and Waltz, F. A., "Investigation of Remote Sensing Techniques for Agricultural Feedlot Pollution Detection", Proceedings of the Eighth International Symposium on Remote Sensing of Environment, University of Michigan, Ann Arbor, Michigan, 1972.

APPENDIX

APPENDIX A

Precipitation and Data Collection

Table A1. PRECIPITATION AND DATA COLLECTION FOR HURON AND REDFIELD, 1971

Date	Precipitation, cm		Data Collection
	Huron	Redfield	
Jan. 11	.10	.05	
12		.30	
13	.05		
14	.13		
17	.03		
20	.08	.05	
25		.08	
27	.03		
28	.03		
29	.03		
Total (Normal)	.48 (1.22)	.48 (1.19)	
Feb. 3	.20	.50	
4	.13	.05	
11	.03		
13	.10	.25	
18	.40		Aerial
19	1.45	.13	
23			Aerial
26	.18		
27	.03		
Total (Normal)	2.52 (1.52)	.93 (1.30)	
March 15	.05		
17	.13		
18	.05		
19	.08		
21	.08		
Total (Normal)	.39 (2.82)	0.00 (2.24)	
April 7			Aerial & Sampling
16	.36	.18	
18		.10	
20	1.88	1.91	
21	.81	1.07	
26	1.52	.66	
27	1.07	3.71	

Table A1. Continued

Date		Precipitation, cm				Data Collection
		Huron		Redfield		
April	28					Sampling
	29					Aerial & Sampling
Total	(Normal)	5.64	(4.67)	7.63	(4.70)	
May	9	.10		.10		
	10	.03				
	11			.18		
	15	.03		.25		
	16	.64				
	17	1.22		.84		
	19					Sampling
	21	.25		.89		
	23	2.31		2.02		
	24	.05		.15		
	26					Aerial & Sampling
	30	.25		.23		
	31	.18		.25		
Total	(Normal)	5.06	(5.99)	4.91	(5.94)	
June	1	.05		.25		
	3			.71		
	4	1.57				
	5			.71		
	7	.13				
	8	.05				
	9	.71		3.22		
	10	.03				
	11					Aerial & Sampling
	12			.10		
	15	.30				
	16	.56		2.46		
	17	.18				
	18	.03				
	19	.74		3.35		
	21	1.90		.56		
	28	.99		.56		
	29	.05		2.92		
Total	(Normal)	7.29	(8.02)	14.84	(9.45)	

Table A1. Continued

Date		Precipitation, cm				Data Collection
		Huron		Redfield		
July	2					Sampling
	3	.13				
	4			.05		
	9			.03		
	11	.03				
	14	.10				
	18	.03		1.07		
	20					Aerial & Sampling
	21			.13		
	22	.38		.38		
	24	1.65		.53		
Total	(Normal)	2.32	(4.60)	2.19	(5.26)	
Aug.	9					Aerial & Sampling
	10			.25		
	13	.03				
	18	1.22		2.44		
	19					Aerial & Sampling
	30	3.08		4.88		
	31	.38		.05		
Total	(Normal)	4.71	(5.26)	7.62	(5.21)	
Sept.	1					Aerial & Sampling
	3	2.54				
	4	.18		4.20		
	5	.20		.10		
	8	.10		.03		
	9			.13		
	21	.36				
	22	.13				
	23					Sampling
	28			.05		
	30	1.02		.50		
Total	(Normal)	4.53	(3.89)	5.01	(3.45)	
Oct.	1	1.19				
	2			1.35		
	12	.03		.10		

Table A1. Continued

Date		Precipitation,cm		Data Collection
		Huron	Redfield	
Oct.	14			Sampling
	15	1.24	.50	
	16	.43	.50	
	17	.03	.10	
	18	.81	1.52	
	27	2.26	1.02	
	28	.56	.36	
	29	.51		
	30	.96	2.02	
Total	(Normal)	8.02 (2.92)	7.47 (3.20)	
Nov.	3			Aerial & Sampling
	13	.13		
	14	.96	.46	
	15	.05		
	16	1.91	1.91	
	17	.50	.05	
	18	.05	.10	
	19	.13		
	25	.03		
	26	.05	.08	
	27	.81	.50	
	28	.53	.50	
	30	.03		
Total	(Normal)	5.18 (1.73)	3.60 (1.52)	
Dec.	1	.08	.20	
	4	.23	.15	
	7	.10		
	8	.13	.20	
	10	.05	.08	
	16	.05		
	29	.13		
	30	.28	.36	
Total	(Normal)	1.05 (1.42)	.99 (1.17)	

Normals are climatological normals based on the period 1931-1960.

APPENDIX B

Aerial Mission Data

Table B1. AERIAL MISSION DATA FOR EACH FLIGHT

Date	Altitude m(agl)	Hasselblad 70 mm					Thermal Scanner	Solameter	Weather Conditions (Clouds, haze)
		B&W Red	B&W Green	B&W Blue	Color IR	Color			
02 18 71	1220					x	x	x	Overcast, Heavy
02 23 71	3660	x				x	x	x	Clear, Light
04 07 71	3050		x	x	x	x	x	x	Clear, Light
	1220		x	x	x	x	x	x	
04 29 71	1220		x	x	x	x	x	x	Overcast, Light
05 26 71	1067		x	x	x	x	x	x	Clear, Moderate
	3050		x	x	x	x	x	x	
06 11 71	1067		x	x	x	x	x	x	Cumulus, Moderate
07 20 71	2067		x	x	x	x	x	x	Clear, Moderate
	3050		x	x	x	x	x	x	
08 09 71	1067		x	x	x	x	x	x	Clear, Light
08 19 71	1067		x	x	x	x	x	x	Clear, Heavy
	3050		x	x	x	x	x	x	
09 01 71	1067		x	x	x	x	x	x	Clear, Heavy
11 03 71	1067		x	x	x	x	x	x	Clear, Moderate
	3050		x	x	x	x	x	x	
03 08 72	1067	x				x			Clear, Moderate
	3050	x				x			
05 04 72	1067		x	x	x	x		x	Clear, Moderate
	3050		x	x	x	x		x	

APPENDIX C

Water Quality Parameter Data

Table C1. WATER QUALITY PARAMETER ANALYSIS FOR APRIL 7, 1971

Sample Site	Time	Temp (^{o}C)	Dissolved Oxygen (ppm)	Biochemical Oxygen Demand (ppm)	Chemical Oxygen Demand (ppm)	Kjeldahl Nitrogen (ppm)	Nitrate Nitrogen NO_3 -N (ppm)	Total Phosphates (ppm)	Total Solids (ppm)
1	0925	4.5	10.68	3.4	110.6	1.7	0.04	1.38	620
2	1000	5.5	11.12	11.1	118.3	2.7	0.14	1.74	726
3	1030	6.0	10.48	11.8	52.0	2.8	0.07	1.92	714
4	1050	7.0	10.12	11.5	128.5	3.0	0.23	2.85	688
5	1125	7.0	10.60	9.5	116.7	3.0	0.12	2.65	496
6	1200	6.0	10.60	2.4	33.0	1.0	0.65	0.37	714
7	1225	7.0	11.40	9.9	108.3	2.4	0.06	1.04	568
8	1255	7.0	11.96	8.9	25.8	2.6	0.08	0.33	520
9	1310	7.5	10.32	5.9	35.8	2.0	0.09	0.40	510
10	1325	8.0	10.20	6.4	32.7	2.5	0.14	0.60	726
11	1345	8.5	10.20	7.2	34.6	1.8	0.03	1.20	622
12	1400	7.5	10.08	7.5	32.7	1.7	0.04	1.34	638

Table C1. Continued

Sample	Total Volatile Solids (ppm)	Total Suspended Solids (ppm)	Total Volatile Suspended Solids (ppm)	pH	Conductivity (micromhos/cm^2 @ 25°C)	Turbidity (ppm of SiO^3)
1	154	12	4	8.42	983	12
2	148	23	11	8.59	1124	15
3	172	16	9	8.67	1135	15
4	150	18	8	8.53	1100	22
5	100	11	6	8.25	757	13
6	210	6	0	8.01	993	3
7	146	31	11	9.29	846	14
8	164	33	12	9.10	767	25
9	114	19	8	9.21	795	8
10	168	132	21	8.65	900	43
11	114	24	7	8.50	903	7
12	120	22	9	8.48	916	13

Table C2. WATER QUALITY PARAMETER ANALYSIS FOR APRIL 28, 1971

Sample Site	Time	Temp (°C)	Dissolved Oxygen (ppm)	Biochemical Oxygen Demand (ppm)	Chemical Oxygen Demand (ppm)	Kjeldahl Nitrogen (ppm)
1	0935	9.5	8.43	7.0	33.0	2.0
2	1000	7.5	10.09	8.0	32.0	2.2
3	1030	7.0	10.36	8.0	31.0	2.4
4	1100	7.5	10.36	6.0	29.0	2.2
5	1125	9.0	9.64	4.0	38.0	2.4
6	1145	5.0	12.71	3.0	34.0	1.0
7	1205	9.5	8.53	5.0	26.0	1.5
8	1225	10.0	8.35	7.0	31.0	2.3
9	1240	9.5	8.84	5.0	31.0	1.8
10	1255	10.0	8.98	20.0	36.0	1.7
11	1315	10.0	7.31	6.0	29.0	2.1
12	1340	8.5	10.58	6.0	34.0	2.0
13	1355	9.5	9.10	5.0	32.0	1.9
14	1410	9.0	8.43	5.0	33.0	2.0

Table C2. Continued

Sample Site	Nitrate Nitrogen NO_3 -N (ppm)	Total Phosphates (ppm)	Total Solids (ppm)	Total Volatile Solids (ppm)	Total Suspended Solids (ppm)	Total Volatile Suspended Solids (ppm)
1	0.10	0.76	736	198	35	9
2	0.12	0.65	634	316	38	10
3	0.15	0.94	648	400	26	8
4	0.14	1.37	672	444	51	14
5	0.06	0.59	990	552	7	3
6	0.37	0.67	874	372	2	2
7	0.06	0.81	780	340	22	8
8	0.11	0.98	754	386	54	15
9	0.08	1.22	732	328	34	9
10	0.17	0.67	674	148	73	16
11	0.14	2.36	648	210	34	9
12	0.11	1.34	670	456	21	9
13	0.10	2.51	598	216	35	9
14	0.06	2.20	622	266	21	6

Table C2. Continued

Sample Site	pH	Conductivity (micromhos/cm^2 @ 25^{0}C)	Turbidity (ppm of SiO_3)	Total Coliform (MPN)[1]	Fecal Coliform (MPN)	Fecal Streptococcus (MPN)
1	8.31	1028	29	200	0	0
2	8.34	871	29	2,300	2,300	500
3	7.87	922	19	13,000	7,900	200
4	8.22	934	58	1,700	0	0
5	8.57	1311	18	700	200	0
6	8.22	1200	6	7,900	1,700	700
7	8.51	1067	23	1,700	0	0
8	8.32	1022	43	130,000	130,000	10,900
9	8.48	1045	31	4,900	2,200	0
10	8.40	1100	28	0	0	0
11	8.22	867	33	1,700	500	200
12	8.01	845	15	500	0	200
13	8.23	845	19	200	200	0
14	8.22	867	26	500	0	0

[1] Most Probable number--number of organisms per 100 milliliters of sample

Table C3. WATER QUALITY PARAMETER ANALYSIS FOR APRIL 29, 1971

Sample Site	Time	Temp (°C)	Dissolved Oxygen (ppm)	Biochemical Oxygen Demand (ppm)	Chemical Oxygen Demand (ppm)	Kjeldahl Nitrogen (ppm)
1	0925	9.0	9.13	7.0	56.0	2.4
2	0950	8.0	12.40	9.0	25.0	1.8
3	1015	8.0	11.73	7.0	54.0	1.9
4	1040	8.5	10.53	5.0	20.0	1.9
5	1105	9.5	9.27	5.0	28.0	1.7
6	1125	6.5	13.07	3.0	21.0	0.7
7	1145	9.5	8.83	3.0	22.0	1.9
8	1200	10.5	9.40	5.0	32.0	2.0
9	1215	9.5	9.60	4.0	24.0	1.9
10	1230	11.5	9.87	6.0	25.0	2.1
11	1245	10.0	7.67	3.0	18.0	1.8
12	1300	10.0	11.33	6.0	22.0	2.0
13	1315	10.5	8.93	3.0	30.0	1.7
14	1330	9.5	8.57	4.0	23.0	1.8

Table C3. Continued

Sample Site	Nitrate Nitrogen No_3 -N (ppm)	Total Phosphates (ppm)	Total Solids (ppm)	Total Volatile Solids (ppm)	Total Suspended Solids (ppm)	Total Volatile Suspended Solids (ppm)
1	0.12	1.42	698	222	24	8
2	0.08	1.41	626	154	39	12
3	0.05	1.01	638	154	32	12
4	0.30	0.83	642	158	40	13
5	0.06	1.65	870	218	10	5
6	0.26	1.04	820	150	4	4
7	0.12	0.84	792	186	13	8
8	0.33	1.28	766	172	29	13
9	0.07	1.23	742	224	37	10
10	0.07	0.59	686	228	35	12
11	0.13	1.21	624	208	31	7
12	0.10	1.32	622	134	27	9
13	0.08	0.97	576	134	26	3
14	0.05	1.46	596	156	18	7

TABLE C3. Continued

Sample Site	pH	Conductivity (micromhos/cm^2 @ 25^{0}C)	Turbidity (ppm of SiO_3)	Total Coliform (MPN)[1]	Fecal Coliform (MPN)	Fecal Streptococcus (MPN)
1	8.47	1045	26	1,300	790	50
2	8.51	889	23	7,900	7,900	790
3	8.46	911	20	3,300	3,300	210
4	8.31	911	52	490	490	80
5	8.63	1311	14	490	140	50
6	8.14	1200	6	490	490	20
7	8.49	1156	18	330	130	0
8	8.57	1089	39	4,000	3,300	220
9	8.62	1045	27	940	330	170
10	8.61	1022	20	50	20	20
11	8.30	878	22	1,090	700	80
12	7.99	889	24	130	130	40
13	8.27	839	17	170	80	0
14	8.33	856	22	330	130	20

Most Probable Number--number of organisms per 100 milliliters of sample.

Table C4. WATER QUALITY PARAMETER ANALYSIS FOR MAY 19, 1971

Sample Site	Time	Temp (^{0}C)	Dissolved Oxygen (ppm)	Biochemical Oxygen Demand (ppm)	Chemical Oxygen Demand (ppm)	Kjeldahl Nitrogen (ppm)
1	0925	15.5	7.22	5.0	28.0	1.6
2	0955	13.0	8.51	7.0	30.0	1.7
3	1010	13.0	8.20	8.0	33.0	1.6
4	1030	12.5	8.07	8.0	28.0	1.6
5	1100	15.0	6.84	7.0	30.0	1.7
6	1120	10.0	11.55	4.0	22.0	0.8
7	1140	15.0	6.43	6.0	36.0	1.6
8	1200	16.0	6.29	4.0	30.0	1.6
9	1215	15.0	7.18	5.0	31.0	1.5
10	1225	15.0	7.11	6.0	26.0	1.7
11	1250	16.0	6.15	8.0	33.0	1.5
12	1305	12.0	8.89	8.0	36.0	1.8
13	1320	15.0	6.29	5.0	31.0	1.9
14	1335	15.0	6.43	7.0	34.0	1.9

Table C4. Continued

Sample Site	Nitrate Nitrogen NO_3 -N (ppm)	Total Phosphates (ppm)	Total Solids (ppm)	Total Volatile Solids (ppm)	Total Suspended Solids (ppm)	Total Volatile Suspended Solids (ppm)
1	0.07	0.69	724	202	42	11
2	0.08	0.80	790	228	63	13
3	0.07	0.71	778	200	52	12
4	0.08	0.68	810	212	70	17
5	0.08	1.21	742	222	34	8
6	0.25	1.76	838	200	7	0
7	0.10	1.56	648	122	40	9
8	0.07	1.40	752	224	41	8
9	0.08	1.35	790	182	52	5
10	0.50	1.61	808	174	43	4
11	0.17	2.10	992	226	49	8
12	0.06	1.12	842	194	24	8
13	0.06	2.20	904	246	57	7
14	0.04	2 14	920	350	64	8

Table C4. Continued

Sample Site	pH	Conductivity (micromhos/cm^2 @ 25^{0}C)	Turbidity (ppm of SiO_3)	Total Coliform (MPN)[1]	Fecal Coliform (MPN)	Fecal Streptococcus (MPN)
1	8.31	1054	29	310	20	33
2	8.26	1112	35	1,300	200	50
3	8.28	1102	43	1,300	20	0
4	8.27	1107	31	330	130	130
5	8.31	1084	33	1,300	172	109
6	8.29	1237	8	2,300	490	1,090
7	8.29	998	35	790	109	79
8	7.99	1070	35	2,300	500	79
9	8.29	1086	33	1,300	200	221
10	7.79	1167	29	230	80	49
11	8.24	1383	33	2,300	220	230
12	8.31	1144	22	1,300	330	230
13	8.22	1206	29	1,090	94	109
14	8.22	1294	35	230	49	23

[1] Most Probable Number--number of organisms per 100 milliliters of sample

Table C5. WATER QUALITY PARAMETER ANALYSIS FOR MAY 26, 1971

Sample Site	Time	Temp (^oC)	Dissolved Oxygen (ppm)	Biochemical Oxygen Demand (ppm)	Chemical Oxygen Demand (ppm)	Kjeldahl Nitrogen (ppm)
1	0930	13.5	9.41	8.0	35.0	1.5
2	0950	12.0	10.32	6.0	38.0	1.7
3	1010	12.5	10.39	6.0	33.0	1.7
4	1025	12.5	10.49	7.0	34.0	1.7
5	1050	13.5	7.86	3.0	32.0	2.0
6	1110	11.5	6.75	3.0	27.0	1.4
7	1135	14.5	7.71	3.0	33.0	1.9
8	1150	14.5	8.35	3.0	32.0	1.8
9	1210	15.0	8.35	3.0	27.5	1.8
10	1215	15.0	9.33	4.0	34.0	1.9
11	1230	16.0	8.63	6.0	34.0	1.8
12	1240	18.0	8.07	14.0	50.0	2.2
13	1300	14.0	6.39	4.0	32.0	1.8
14	1310	15.0	8.20	6.0	33.0	1.8

Table C5. Continued

Sample Site	Nitrate Nitrogen NO_3 -N (ppm)	Total Phosphates (ppm)	Total Solids (ppm)	Total Volatile Solids (ppm)	Total Suspended Solids (ppm)	Total Volatile Suspended Solids (ppm)
1	0.04	0.98	776	122	25	8
2	0.04	0.78	830	128	46	16
3	0.03	0.86	848	162	27	20
4	0.03	0.94	880	152	25	9
5	0.08	1.42	720	114	19	7
6	0.13	1.52	798	134	12	7
7	0.07	1.37	868	140	23	6
8	0.07	1.44	934	140	12	5
9	0.06	1.54	942	210	22	7
10	0.13	1.55	936	136	61	14
11	0.08	1.72	896	154	30	7
12	0.11	0.86	974	152	41	21
13	0.12	1.96	812	162	67	17
14	0.12	1.71	792	138	33	12

Table C5. Continued

Sample Site	pH	Conductivity (micromhos/cm^2 @ 25°C)	Turbidity (ppm of SiO_3)	Total Coliform (MPN)[1]	Fecal Coliform (MPN)	Fecal Streptococcus (MPN)
1	8.33	1136	26	1,300	221	27
2	8.38	1175	24	790	210	33
3	8.43	1198	17	2,210	330	170
4	8.44	1221	21	490	33	13
5	8.34	1070	20	490	49	33
6	8.28	1134	17	790	490	330
7	8.36	1144	26	790	790	39
8	8.31	1368	31	3,700	800	48
9	8.39	1337	26	700	210	48
10	8.32	1282	33	1,090	310	70
11	8.30	1230	31	4,900	630	790
12	8.15	1310	19	330	40	170
13	8.32	1134	52	330	5	79
14	8.34	1121	31	80	23	17

[1] Most Probable Number--number of organisms per 100 milliliters of sample

Table C6. WATER QUALITY PARAMETER ANALYSIS FOR JUNE 11, 1971

Sample Site	Time	Temp (^{o}C)	Dissolved Oxygen (ppm)	Biochemical Oxygen Demand (ppm)	Chemical Oxygen Demand (ppm)	Kjeldahl Nitrogen (ppm)
1	1000	23.0	6.99	1.0	40.0	2.0
2	1020	22.5	7.44	4.0	43.0	2.4
3	1035	22.0	6.63	4.0	38.0	2.6
4	1055	22.5	7.47	3.0	41.0	2.3
5	1125	23.0	8.27	2.0	38.0	1.7
6	1140	23.5	3.65	2.0	31.0	1.8
7	1200	22.5	7.48	3.0	49.0	1.9
8	1220	23.0	8.06	2.0	45.0	2.1
9	1235	23.0	6.68	4.0	47.0	1.9
10	1250	23.5	8.36	2.0	47.0	2.0
11	1305	23.0	10.13	6.0	60.0	2.8
12	1315	25.0	8.40	7.0	44.0	3.0
13	1330	23.5	7.69	4.0	35.0	2.4
14	1340	23.0	6.44	3.0	39.0	2.4

Table C6. Continued

Sample Site	Nitrate Nitrogen NO_3 -N (ppm)	Total Phosphates (ppm)	Total Solids (ppm)	Total Volatile Solids (ppm)	Total Suspended Solids (ppm)	Total Volatile Suspended Solids (ppm)
1	0.06	1.42	884	188	23	5
2	0.11	0.73	902	224	73	8
3	0.10	1.59	872	214	63	11
4	0.07	1.81	1324	214	61	11
5	0.05	1.83	806	186	26	3
6	0.19	3.11	830	178	47	7
7	0.11	2.13	774	194	33	4
8	0.14	2.40	794	190	38	8
9	0.10	2.18	898	220	28	5
10	0.09	2.25	990	206	29	3
11	0.09	2.78	1150	262	28	5
12	0.19	1.57	966	226	41	4
13	0.13	3.02	1156	292	48	1
14	0.11	3.11	1134	264	47	1

Table C6. Continued

Sample Site	pH	Conductivity (micromhos/cm @ 25°C)[2]	Turbidity (ppm of SiO_3)	Total Coliform (MPN)[1]	Fecal Coliform (MPN)	Fecal Streptococcus (MPN)
1	8.19	1177	29	230	49	23
2	8.25	1148	43	170	170	33
3	8.21	1134	45	790	790	170
4	8.28	1099	35	230	130	130
5	8.41	1104	27	221	49	22
6	8.15	1094	32	3,480	3,480	16,000
7	8.21	990	35	460	460	240
8	8.23	1069	29	2,210	1,720	1,600
9	8.21	1153	18	348	348	920
10	8.32	1277	19	348	348	172
11	8.30	1445	10	920,000	2,300	1,720
12	8.05	1242	32	34,800	17,200	1,600
13	8.21	1406	27	330	330	920
14	8.15	1416	30	80	49	94

[1] Most Probable Number--number of organisms per 100 milliliters of sample

Table C7. WATER QUALITY PARAMETER ANALYSIS FOR JULY 2, 1971

Sample Site	Time	Temp (°C)	Dissolved Oxygen (ppm)	Biochemical Oxygen Demand (ppm)	Chemical Oxygen Demand (ppm)	Kjeldahl Nitrogen (ppm)
1	0925	24.5	8.10	4.6	36.6	2.0
2	0945	23.5	8.30	5.8	41.3	2.3
3	1005	23.5	7.14	4.4	37.7	2.3
4	1020	24.0	7.29	4.9	34.7	2.2
5	1045	25.0	8.69	3.7	37.0	2.0
6	1100	24.5	5.55	7.8	43.1	2.8
7	1130	24.0	6.27	7.5	42.2	2.5
8	1150	24.5	6.27	3.8	34.7	2.2
9	1200	25.0	6.57	4.9	41.5	2.2
10	1210	24.5	4.65	4.0	35.6	2.4
11	1220	25.0	6.83	4.0	35.2	2.3
12	1230	27.0	11.57	9.5	41.1	2.8
13	1250	24.0	4.72	4.8	42.5	2.4
14	1300	25.0	7.19	4.6	33.4	2.4

Table C7. Continued

Sample Site	Nitrate Nitrogen NO_3 -N (ppm)	Total Phosphates (ppm)	Total Solids (ppm)	Total Volatile Solids (ppm)	Total Suspended Solids (ppm)	Total Volatile Suspended Solids (ppm)
1	0.08	1.14	860	196	27	7
2	0.04	2.09	860	196	75	13
3	0.10	1.92	874	156	69	12
4	0.13	2.07	896	236	69	12
5	0.06	2.26	930	196	25	5
6	0.27	2.98	914	192	94	16
7	0.11	2.47	978	184	39	7
8	0.13	2.39	946	182	43	8
9	0.11	3.66	926	184	36	6
10	0.13	2.15	1000	240	73	7
11	0.12	1.24	892	164	46	7
12	0.12	1.27	960	212	42	9
13	0.20	1.26	948	230	92	14
14	0.15	1.64	894	190	61	7

Table C7. Continued

Sample Site	pH	Conductivity (micromhos/cm^2 @ 25^{0}C)	Turbidity (ppm of SiO_3)	Total Coliform (MPN)[1]	Fecal Coliform (MPN)	Fecal Streptococcus (MPN)
1	8.49	1287	28	310	9	46
2	8.54	1230	41	490	542	240
3	8.42	1235	39	3,480	3,480	330
4	8.49	1255	49	170	112	49
5	8.62	1313	22	490	70	109
6	8.27	1241	35	10,900	10,900	16,000
7	8.38	1433	41	700	49	221
8	8.36	1348	39	1,720	700	1,300
9	8.38	1332	38	2,400	1,300	460
10	8.30	1337	41	490	240	79
11	8.28	1273	44	3,100	490	170
12	8.45	1348	29	22,100	14,100	1,090
13	8.37	1246	66	2,400	240	110
14	8.41	1240	39	330	130	70

[1] Most Probable Number--number of organisms per 100 milliliters of sample

Table C8. WATER QUALITY PARAMETER ANALYSIS FOR JULY 20, 1971

Sample Site	Time	Temp (^oC)	Dissolved Oxygen (ppm)	Biochemical Oxygen Demand (ppm)	Chemical Oxygen Demand (ppm)	Kjeldahl Nitrogen (ppm)
1	1015	24.0	8.06	8.0	43.4	2.6
2	1045	23.0	7.91	7.0	46.3	2.4
3	1100	23.5	8.35	7.0	34.6	2.3
4	1135	23.5	7.97	7.0	38.5	2.5
5	1205	24.0	8.20	8.0	41.3	2.4
6	1225	25.0	8.98	5.0	35.2	2.0
7	1245	24.5	10.55	11.0	42.7	2.8
8	1310	23.5	6.49	6.0	42.7	2.3
9	1325	25.5	10.91	17.0	42.4	2.9
10	1335	24.0	6.62	8.0	43.4	2.1
11	1350	25.0	6.97	10.0	39.8	2.2
12	1400	28.5	12.19	7.0	37.0	2.0
13	1430	23.5	7.49	8.0	34.6	2.3
14	1440	26.0	6.97	8.0	36.9	2.2

Table C8. CONTINUED

Sample Site	Nitrate Nitrogen NO_3 -N (ppm)	Total Phosphates (ppm)	Total Solids (ppm)	Total Volatile Solids (ppm)	Total Suspended Solids (ppm)	Total Volatile Suspended Solids (ppm)
1	0.08	2.65	1046	208	50	11
2	0.05	3.02	990	172	49	10
3	0.11	3.03	1184	678	44	8
4	0.11	3.09	978	434	52	9
5	0.08	2.99	800	154	41	9
6	0.07	2.95	772	150	21	2
7	0.08	2.90	768	184	31	8
8	0.21	3.07	762	394	62	7
9	0.09	2.96	778	208	32	11
10	0.23	3.20	810	322	107	9
11	0.15	3.09	726	168	56	11
12	0.06	2.67	758	124	26	9
13	0.20	3.24	894	172	100	14
14	0.17	3.19	832	164	58	10

Table C8. Continued

Sample Site	pH	Conductivity (micromhos/cm^2 @ 25^{o}C)	Turbidity (ppm of SiO_3)	Total Coliform (MPN)[1]	Fecal Coliform (MPN)	Fecal Streptococcus (MPN)
1	8.26	1439	50	2,400	70	348
2	8.30	1422	33	1,410	542	109
3	8.21	1422	43	3,480	1,090	50
4	8.21	1389	32	330	130	17
5	8.24	1178	23	330	70	33
6	8.38	1167	19	1,700	500	700
7	8.22	1017	14	170	20	49
8	8.31	1078	28	1,720	1,720	260
9	8.21	1084	31	490	330	110
10	8.25	1067	41	790	23	23
11	8.21	1067	41	2,300	1,700	480
12	8.26	1156	14	4,900	900	20
13	8.28	1072	45	490	33	33
14	8.12	1067	41	790	33	49

[1] Most Probable Number--number of organisms per 100 milliliters of sample

Table C9. WATER QUALITY PARAMETER ANALYSIS FOR AUGUST 9, 1971

Sample Site	Time	Temp (^{o}C)	Dissolved Oxygen (ppm)	Biochemical Oxygen Demand (ppm)	Chemical Oxygen Demand (ppm)	Kjeldahl Nitrogen (ppm)
1	1005	23.5	6.72	5.0	47.0	2.0
2	1030	23.0	7.02	7.0	47.0	2.5
3	1050	23.0	7.44	7.0	43.0	2.4
4	1115	23.0	6.72	6.0	49.0	2.3
5	1145	24.0	8.21	6.0	43.0	2.0
6	1210	25.5	8.02	6.0	37.0	2.2
7	1225	24.0	7.15	9.0	44.0	2.2
8	1250	24.0	6.79	7.0	42.0	2.5
9	1310	24.5	7.36	10.0	44.0	2.5
10	1325	24.5	7.10	8.0	46.0	2.4
11	1340	25.5	6.92	8.0	37.0	2.3
12	1355	28.0	11.94	8.0	38.0	2.2
13	1415	24.0	6.58	7.0	47.0	2.4
14	1425	26.5	8.55	7.0	34.0	2.1

Table C9. Continued

Sample Site	Nitrate Nitrogen NO_3 -N (ppm)	Total Phosphates (ppm)	Total Solids (ppm)	Total Volatile Solids (ppm)	Total Suspended Solids (ppm)	Total Volatile Suspended Solids (ppm)
1	0.12	1.09	878	193	52	15
2	0.15	1.64	805	162	80	19
3	0.14	1.38	799	194	55	15
4	0.14	1.47	799	145	67	17
5	0.12	1.44	707	113	36	13
6	0.17	1.47	753	167	45	13
7	0.10	1.27	718	155	34	7
8	0.09	1.40	720	150	46	12
9	0.10	1.63	710	122	32	11
10	0.09	1.54	696	137	72	14
11	0.12	1.94	724	179	35	8
12	0.12	1.36	702	152	35	13
13	0.14	1.68	736	202	91	18
14	0.13	1.74	716	206	42	10

Table C9. Continued

Sample Site	pH	Conductivity (micromhos/cm^2 @ 25^{0}C)	Turbidity (ppm of SiO_3)	Total Coliform (MPN)[1]	Fecal Coliform (MPN)	Fecal Streptococcus (MPN)
1	8.59	1238	39	50	49	70
2	8.66	1154	43	20	17	13
3	8.63	1159	43	790	790	542
4	8.57	1154	39	80	49	59
5	8.63	1049	30	170	79	17
6	8.46	1101	46	2,210	1,720	1,090
7	8.43	1086	24	170	33	13
8	8.42	1059	35	330	170	230
9	8.45	1075	28	330	330	345
10	8.47	1070	30	130	49	23
11	8.47	1091	30	790	790	170
12	8.82	1107	19	16,000	16,000	240
13	8.53	1070	49	170	172	40
14	8.61	1070	33	80	49	17

[1] Most Probable Number--number of organisms per 100 milliliters of sample

Table C10. WATER QUALITY PARAMETER ANALYSIS FOR AUGUST 19, 1971

Sample Site	Time	Temp (°C)	Dissolved Oxygen (ppm)	Biochemical Oxygen Demand (ppm)	Chemical Oxygen Demand (ppm)	Kjeldahl Nitrogen (ppm)
1	1000	24.0	4.18	3.0	33.0	2.1
2	1025	22.5	5.66	4.0	44.0	2.2
3	1045	22.5	6.35	4.0	45.0	2.4
4	1105	23.0	6.15	4.0	50.0	2.2
5	1140	23.5	6.80	6.0	48.0	2.0
6	1210	21.0	2.55	8.0	51.0	2.7
7	1235	24.5	6.92	2.0	34.0	1.9
8	1250	24.5	5.16	4.0	37.0	1.8
9	1305	24.5	6.67	3.0	38.0	1.8
10	1320	25.0	6.29	3.0	60.0	2.3
11	1340	25.0	6.35	3.0	38.0	1.8
12	1350	26.5	10.94	7.0	46.0	2.2
13	1415	24.0	7.42	5.0	43.0	1.6
14	1425	25.5	10.68	8.0	46.0	2.6

Table C10. Continued

Sample Site	Nitrate Nitrogen NO_3 -N (ppm)	Total Phosphates (ppm)	Total Solids (ppm)	Total Volatile Solids (ppm)	Total Suspended Solids (ppm)	Total Volatile Suspended Solids (ppm)
1	0.13	0.83	808	162	35	4
2	0.12	1.19	786	159	62	17
3	0.09	1.08	814	215	58	17
4	0.12	1.15	738	139	64	15
5	0.09	1.23	686	185	42	12
6	0.37	4.11	486	140	112	28
7	0.08	1.04	709	184	41	12
8	0.13	2.13	747	181	56	9
9	0.10	1.28	709	176	38	8
10	0.21	1.22	735	150	520	56
11	0.06	1.16	723	198	30	5
12	0.06	1.01	676	176	29	14
13	0.08	1.11	724	230	65	11
14	0.07	1.43	726	228	40	15

Table C10. Continued

Sample Site	pH	Conductivity (micromhos/cm^2 @ 25°C)	Turbidity (ppm of SiO_3)	Total Coliform (MPN)[1]	Fecal Coliform (MPN)	Fecal Streptococcus (MPN)
1	8.39	1193	45	172	348	920
2	8.38	1167	39	348	70	221
3	8.39	1156	49	790	490	330
4	8.28	1134	44	348	172	240
5	8.36	1042	41	1,600	1,600	1,600
6	8.01	670	78	160,000	160,000	16,000
7	8.39	1080	31	542	542	221
8	8.42	1086	33	2,210	2,210	1,720
9	8.43	1095	29	2,400	2,400	2,400
10	8.42	1090	78	1,600	278	79
11	8.45	1090	30	3,480	790	221
12	8.41	1079	29	3,480	5,420	330
13	8.43	1074	33	348	79	920
14	8.28	1068	29	240	79	130

[1] Most Probable Number--number of organisms per 100 milliliters of sample

Table C11. WATER QUALITY PARAMETER ANALYSIS FOR SEPTEMBER 1, 1971

Sample Site	Time	Temp (°C)	Dissolved Oxygen (ppm)	Biochemical Oxygen Demand (ppm)	Chemical Oxygen Demand (ppm)	Kjeldahl Nitrogen (ppm)
1	1020	22.0	5.24	2.0	35.0	1.6
2	1045	21.5	7.11	4.0	37.0	1.9
3	1105	21.5	7.53	4.0	40.0	1.8
4	1130	22.0	7.57	3.0	43.0	1.7
5	1200	21.5	5.49	3.0	42.0	1.7
6	1235	22.5	7.82	3.0	41.0	2.1
7	1255	22.0	7.45	4.0	39.0	2.1
8	1325	22.5	6.08	3.0	45.0	2.1
9	1340	22.0	6.08	3.0	45.0	2.0
10	1355	22.5	6.41	3.0	35.0	2.2
11	1415	23.0	5.74	3.0	25.0	2.0
12	1435	25.0	12.40	8.0	36.0	2.5
13	1500	23.0	7.47	4.0	36.0	2.0
14	1515	23.0	7.49	4.0	44.0	1.9

Table C11. Continued

Sample Site	Nitrate Nitrogen NO_3 -N (ppm)	Total Phosphates (ppm)	Total Solids (ppm)	Total Volatile Solids (ppm)	Total Suspended Solids (ppm)	Total Volatile Suspended Solids (ppm)
1	0.08	1.12	815	177	27	5
2	0.16	1.36	802	140	98	18
3	0.17	1.36	813	187	137	26
4	0.11	1.17	797	141	74	15
5	0.09	1.18	747	159	39	8
6	0.32	2.22	939	149	125	21
7	0.09	0.85	760	154	53	9
8	0.13	1.00	771	140	72	13
9	0.10	0.94	739	127	55	10
10	0.13	0.98	773	169	121	19
11	0.09	0.96	742	162	55	13
12	0.08	0.12	719	166	88	20
13	0.08	1.47	727	170	121	19
14	0.10	1.41	729	155	91	19

Table C11. Continued

Sample Site	pH	Conductivity (micromhos/cm^2 @ 25°C)	Turbidity (ppm of SiO_3)	Total Coliform (MPN)[1]	Fecal Coliform (MPN)	Fecal Streptococcus (MPN)
1	8.51	1188	39	310	110	220
2	8.52	1144	60	130	50	50
3	8.57	1139	60	230	230	140
4	8.51	1134	43	230	230	20
5	8.53	1134	30	200	200	330
6	8.52	1210	62	1,300	500	17,000
7	8.49	1101	46	1,300	790	330
8	8.50	1095	51	3,480	3,480	5,420
9	8.54	1090	51	500	500	490
10	8.55	1101	46	490	490	170
11	8.51	1101	41	490	230	490
12	8.59	1090	51	13,000	7,900	1,300
13	8.53	1101	41	170	50	140
14	8.51	1101	43	410	270	220

[1] Most Probable Number--number of organisms per 100 millilters of sample

Table C12. WATER QUALITY PARAMETER ANALYSIS FOR SEPTEMBER 23, 1971

Sample Site	Time	Temp (^{o}C)	Dissolved Oxygen (ppm)	Biochemical Oxygen Demand (ppm)	Chemical Oxygen Demand (ppm)	Kjeldahl Nitrogen (ppm)
1	0950	12.5	7.90	2.0	41.0	1.0
2	1015	11.0	8.16	3.0	48.0	1.5
3	1035	12.0	8.30	1.0	44.0	1.3
4	1100	11.5	8.66	2.0	41.0	1.4
5	1120	13.5	8.62	2.0	42.0	1.2
6	1140	12.0	8.59	3.0	35.0	1.8
7	1200	13.5	8.53	2.0	32.0	2.0
8	1215	13.0	8.74	2.0	46.0	1.7
9	1235	13.0	8.89	3.0	43.0	1.8
10	1245	13.0	8.45	3.0	47.0	1.9
11	1300	13.5	7.64	3.0	37.0	1.4
12	1310	14.0	11.78	6.0	45.0	2.3
13	1325	13.0	8.68	2.0	33.0	1.5
14	1335	12.5	8.72	2.0	34.0	1.6

Table C12. Continued

Sample Site	Nitrate Nitrogen NO_3 -N (ppm)	Total Phosphates (ppm)	Total Solids (ppm)	Total Volatile Solids (ppm)	Total Suspended Solids (ppm)	Total Volatile Suspended Solids (ppm)
1	0.06	0.70	772	219	24	5
2	0.05	0.71	797	156	50	10
3	0.08	0.71	782	182	41	10
4	0.06	0.63	793	215	49	12
5	0.06	0.62	763	222	27	6
6	0.04	0.68	750	244	16	4
7	0.06	0.62	708	225	44	10
8	0.07	0.66	719	229	64	12
9	0.07	1.46	719	207	51	14
10	0.08	0.78	714	206	47	10
11	0.08	0.95	723	248	40	11
12	0.07	0.32	747	216	55	21
13	0.10	1.04	686	220	74	18
14	0.11	1.05	680	296	55	12

Table C12. Continued

Sample Site	pH	Conductivity (micromhos/cm^2 @ 25°C)	Turbidity (ppm of SiO_3)	Total Coliform (MPN)[1]	Fecal Coliform (MPN)	Fecal Streptococcus (MPN)
1	8.48	1125	16	240	240	33
2	8.45	1125	39	49	33	33
3	8.58	1130	39	130	80	70
4	8.60	1120	33	330	330	79
5	8.73	1110	23	20	0	0
6	8.62	1080	33	50	50	130
7	8.71	1043	33	80	80	20
8	8.69	1024	43	1,300	490	1,300
9	8.68	1139	33	230	130	210
10	8.66	1024	39	330	70	20
11	3.69	1070	30	16,000	1,090	490
12	8.63	1080	24	1,720	1,300	220
13	8.68	1109	39	170	50	7
14	8.72	1040	41	170	110	11

[1] Most Probable Number--number of organisms per 100 milliliters of sample

Table C13. WATER QUALITY PARAMETER ANALYSIS FOR OCTOBER 14, 1971

Sample Site	Time	Temp (^oC)	Dissolved Oxygen (ppm)	Biochemical Oxygen Demand (ppm)	Chemical Oxygen Demand (ppm)	Kjeldahl Nitrogen (ppm)
1	0950	11.0	9.50	3.0	50.0	1.0
2	1015	10.0	8.72	4.0	45.0	1.3
3	1035	10.0	9.22	4.0	51.0	1.0
4	1045	10.5	9.11	4.0	35.0	1.2
5	1105	11.0	9.92	4.0	37.0	1.2
6	1120	8.0	8.54	3.0	20.0	0.5
7	1140	10.5	9.13	4.0	44.0	1.6
8	1155	11.5	8.58	5.0	34.0	1.7
9	1205	11.0	8.84	4.0	40.0	1.6
10	1215	10.5	9.24	4.0	47.0	1.8
11	1235	11.0	8.38	3.0	34.0	1.9
12	1245	12.0	3.67	15.0	62.0	2.2
13	1300	11.5	9.25	3.0	41.0	1.5
14	1315	11.0	9.25	3.0	43.0	1.9

Table C13. Continued

Sample Site	Nitrate Nitrogen NO_3 -N (ppm)	Total Phosphates (ppm)	Total Solids (ppm)	Total Volatile Solids (ppm)	Total Suspended Solids (ppm)	Total Volatile Suspended Solids (ppm)
1	0.09	0.67	778	116	12	7
2	0.07	0.80	820	126	56	12
3	0.08	0.87	820	176	50	12
4	0.11	0.90	855	141	82	15
5	0.10	1.03	742	142	52	10
6	0.09	1.36	830	172	23	5
7	0.20	1.24	745	152	51	11
8	0.19	1.30	749	147	47	10
9	0.14	1.41	728	134	58	12
10	0.16	2.11	714	180	170	26
11	0.10	1.34	746	150	48	13
12	0.07	1.72	784	191	38	13
13	0.07	1.27	743	167	98	18
14	0.06	1.22	737	193	77	17

Table C13. Continued

Sample Site	pH	Conductivity (micromhos/cm^2 @ 25^{0}C)	Turbidity (ppm of SiO_3)	Total Coliform (MPN)[1]	Fecal Coliform (MPN)	Fecal Streptococcus (MPN)
1	8.80	1084	26			
2	8.80	1107	54	5	0	0
3	8.71	1126	38	79	2	0
4	8.78	1120	57	0	0	0
5	8.80	1037	38	0	0	0
6	8.48	1147	24	2	2	0
7	8.78	1037	43	0	0	0
8	8.73	1042	33	0	0	0
9	8.73	1042	36	2	8	0
10	8.71	1032	56	2	0	0
11	8.67	1042	24	20	0	0
12	8.28	1147	26	0	0	0
13	8.65	1042	41	2	2	0
14	8.61	1032	45			

[1] Most Probable Number--number of organisms per 100 milliliters of sample

Table C14. WATER QUALITY PARAMETER ANALYSIS FOR NOVEMBER 3, 1971

Sample Site	Time	Temp (^{o}C)	Dissolved Oxygen (ppm)	Biochemical Oxygen Demand (ppm)	Chemical Oxygen Demand (ppm)	Kjeldahl Nitrogen (ppm)	Nitrate Nitrogen NO_3 -N (ppm)	Total Phosphates (ppm)	Total Solids (ppm)
1	1015	4.0	10.94	1.0	27.0	1.2	0.02	1.00	732
2	1035	3.0	10.97	1.0	24.0	1.1	0.06	1.17	771
3	1055	3.0	10.82	1.0	30.0	1.4	0.08	1.28	765
4	1125	4.0	10.69	1.0	27.0	1.3	0.10	1.27	773
5	1150	4.0	8.27	1.0	28.0	1.5	0.06	1.11	721
6	1205	3.0	11.70	1.0	10.0	0.5	0.75	1.08	783
7	1225	5.0	9.87	3.0	32.0	1.5	0.02	1.38	703
8	1240	5.0	9.97	2.0	26.0	1.2	0.14	1.64	684
9	1255	4.0	10.16	2.0	32.0	1.0	0.10	1.08	668
10	1305	5.0	10.94	2.0	27.0	1.3	0.11	1.04	674
11	1315	4.0	10.44	3.0	30.0	1.4	0.08	2.65	692
12	1325	5.5	6.51	8.0	49.0	3.8	0.22	3.59	738
13	1340	4.5	10.09	2.0	29.0	1.0	0.10	1.38	697
14	1350	4.5	9.72	2.0	29.0	1.0	0.10	1.36	783

Table C14. Continued

Sample Site	Total Volatile Solids (ppm)	Total Suspended Solids (ppm)	Total Volatile Suspended Solids (ppm)	pH	Conductivity (micromhos/cm^2 @ 25°C)	Turbidity (ppm of SiO_3)
1	170	17	8	8.66	1033	17
2	142	24	4	8.68	1116	43
3	168	27	8	8.82	1126	31
4	195	24	9	8.82	1126	31
5	161	11	6	8.72	1042	26
6	173	16	4	8.48	1126	16
7	187	10	4	8.69	987	16
8	149	7	4	8.60	1006	13
9	178	14	4	8.60	1001	9
10	158	14	6	8.61	1001	16
11	164	21	5	8.81	1016	25
12	185	44	17	8.22	1094	26
13	159	22	6	8.62	1021	30
14	168	19	4	8.54	1042	22

Table C15. WATER QUALITY PARAMETER ANALYSIS FOR MAY 4, 1972

Sample Site	Time	Temp (^{o}C)	Dissolved Oxygen (ppm)	Biochemical Oxygen Demand (ppm)	Chemical Oxygen Demand (ppm)	Kjeldahl Nitrogen (ppm)	Nitrogen NO_3 -N (ppm)	Total Phosphates (ppm)	Total Solids (ppm)
1	1355	12.0	8.25	8.0	22.5	1.7	0.22	0.51	597
2	1420	12.5	8.16	11.0	22.5	1.7	0.18	0.72	464
3	1440	13.5	8.25	4.0	25.4	1.8	0.16	0.58	494
4	1450	12.5	7.90	3.0	24.4	1.8	0.16	0.75	488
5	1515	12.5	7.30	8.0	20.6	1.7	0.16	0.74	546
6	1525	18.0	9.36	8.0	43.6	3.1	0.57	2.12	488
7	1545	13.0	8.51	3.0	23.4	1.6	0.16	0.67	435
8	1600	13.0	7.74	2.0	26.1	1.7	0.13	0.76	446
9	1615	13.0	7.74	3.0	23.9	1.6	0.17	0.61	431
10	1625	13.0	8.16	2.0	26.1	1.6	0.17	0.76	421
11	1640	13.5	7.62	4.0	27.1	1.8	0.16	0.71	419
12	1645	18.0	7.05	9.0	30.5	2.3	0.66	1.28	540
13	1700	13.0	8.44	11.0	29.0	1.7	0.14	0.76	429
14	1720	13.5	8.41	6.0	23.4	1.7	0.12	0.63	402

Table C15. Continued

Sample Site	Total Volatile Solids (ppm)	Total Suspended Solids (ppm)	Total Volatile Suspended Solids (ppm)	pH	Conductivity (micromhos/cm^2 @ 25^{0}C)	Trubidity (ppm of SiO_3)
1	160	53	11	8.15	838	32
2	203	45	8	8.11	699	11
3	248	30	7	8.20	694	22
4	212	37	7	8.12	689	15
5	282	22	5	8.11	665	13
6	135	24	8	8.15	824	18
7	177	25	4	8.12	647	8
8	197	50	11	8.21	636	6
9	102	33	5	8.10	636	12
10	112	60	11	8.19	638	29
11	95	37	7	8.12	636	11
12	202	19	6	8.08	821	22
13	107	51	8	8.15	610	9
14	93	39	6	8.12	631	11

APPENDIX D

Detailed Statistical Results

Table D1. ANALYSIS OF VARIANCE OF WATER QUALITY PARAMETERS

Water Quality Parameter	Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F
Temperature	Dates (D)	11	5780.42	524.49	834.50**
	Feedlots (F)	3	95.10	31.70	50.25**
	Sites (S)	2	0.29	0.15	2.38
	DF	33	25.88	0.78	1.24
	DS	22	41.83	1.90	3.02**
	FS	6	34.24	5.71	9.06**
	DFS	66	41.47	0.63	
	Total	143	6019.22		
Kjeldahl Nitrogen	Dates (D)	11	13.07	1.19	19.85**
	Feedlots (F)	3	1.17	0.39	6.50**
	Sites (S)	2	0.02	0.01	0.17
	DF	33	4.45	0.13	2.17**
	DS	22	1.81	0.08	1.33
	FS	6	1.44	0.24	4.00**
	DFS	66	4.26	0.06	
	Total	143	26.21		
Biochemical Oxygen Demand	Dates (D)	11	377.04	34.28	6.93**
	Feedlots (F)	3	42.76	14.25	2.88*
	Sites (S)	2	24.40	12.20	2.46
	DF	33	207.47	6.29	1.27
	DS	22	67.51	3.07	0.62
	FS	6	102.28	17.05	3.44**
	DFS	66	326.95	4.95	
	Total	143	1148.40		
Chemical Oxygen Demand	Dates (D)	11	3976.79	361.53	8.42**
	Feedlots (F)	3	314.45	104.82	2.44
	Sites (S)	2	28.20	14.10	0.33
	DF	33	1383.83	41.93	0.98
	DS	22	673.55	30.62	0.71
	FS	6	484.10	80.68	1.88
	DFS	66	2834.68	42.95	
	Total	143	9695.60		

Table D1. Continued

Water Quality Parameter	Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F
Dissolved Oxygen	Dates (D)	11	158.72	14.43	8.29**
	Feedlots (F)	3	11.88	3.96	2.28
	Sites (S)	2	22.00	11.00	6.32**
	DF	33	79.22	2.40	1.38
	DS	22	67.30	3.06	1.76*
	FS	6	39.07	6.51	3.74**
	DFS	66	114.97	1.74	
	Total	143	493.16		
Nitrate Nitrogen	Dates (D)	11	0.062	0.006	1.50
	Feedlots (F)	3	0.027	0.009	2.25
	Sites (S)	2	0.012	0.006	1.50
	DF	33	0.107	0.003	0.75
	DS	22	0.063	0.003	0.75
	FS	6	0.151	0.025	6.25**
	DFS	66	0.286	0.004	
	Total	143			
Total Phosphates	Dates (D)	11	48.53	4.41	31.50**
	Feedlots (F)	3	2.91	0.97	6.93**
	Sites (S)	2	0.10	0.05	0.36
	DF	33	13.16	0.40	2.86**
	DS	22	3.54	0.16	1.14
	FS	6	4.36	0.73	5.21**
	DFS	66	9.53	0.14	
	Total	143	82.14		
pH	Dates (D)	11	3.30	0.30	30.00**
	Feedlots (F)	3	0.07	0.02	2.00
	Sites (S)	2	0.10	0.05	5.00**
	DF	33	0.89	0.03	3.00**
	DS	22	0.34	0.02	2.00*
	FS	6	0.20	0.03	3.00*
	DFS	66	0.55	0.01	
	Total	143	5.45		

Table D1. Continued

Water Quality Parameter	Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F
Conductivity	Dates (D)	11	97.00x10^{4}	8.82x10^{4}	20.05**
	Feedlots (F)	3	0.57x10^{4}	0.19x10^{4}	0.43
	Sites (S)	2	106.10x10^{4}	3.22x10^{4}	7.32**
	DF	33	0.66x10^{4}	0.33x10^{4}	0.75
	DS	22	6.54x10^{4}	0.30x10^{4}	0.68
	FS	6	1.76x10^{4}	0.29x10^{4}	0.66
	DFS	66	29.30x10^{4}	0.44x10^{4}	
	Total	143	241.92x10^{4}		
Total Solids	Dates (D)	11	95.89x10^{4}	87.17x10^{3}	22.64**
	Feedlots (F)	3	3.49x10^{4}	11.64x10^{3}	3.02*
	Sites (S)	2	0.11x10^{4}	0.56x10^{3}	0.15
	DF	33	66.47x10^{4}	20.14x10^{3}	5.23**
	DS	22	11.78x10^{4}	5.35x10^{3}	1.39
	FS	6	1.88x10^{4}	3.14x10^{3}	0.82
	DFS	66	25.39x10^{4}	3.85x10^{3}	
	Total	143	205.00x10^{4}		
Total Volatile Solids	Dates (D)	11	42.80x10^{4}	38.91x10^{3}	11.18**
	Feedlots (F)	3	0.91x10^{4}	3.05x10^{3}	0.88
	Sites (S)	2	0.18x10^{4}	0.90x10^{3}	0.26
	DF	33	21.49x10^{4}	6.51x10^{3}	1.87*
	DS	22	4.39x10^{4}	1.99x10^{3}	0.57
	FS	6	2.89x10^{4}	4.82x10^{3}	1.39
	DFS	66	22.99x10^{4}	3.48x10^{3}	
	Total	143	95.64x10^{4}		
Suspended Solids	Dates (D)	11	5.55x10^{4}	5.05x10^{3}	2.95**
	Feedlots (F)	3	1.81x10^{4}	6.05x10^{3}	3.54*
	Sites (S)	2	2.12x10^{4}	10.59x10^{3}	6.19**
	DF	33	5.30x10^{4}	1.61x10^{3}	0.94
	DS	22	3.63x10^{4}	1.65x10^{3}	0.96*
	FS	6	2.76x10^{4}	4.60x10^{3}	2.69*
	DFS	66	11.30x10^{4}	1.71x10^{3}	
	Total	143	32.47x10^{4}		

Table D1. Continued

Water Quality Parameter	Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F
Volatile Suspended Solids	Dates (D)	11	1.41×10^{3}	1.28×10^{2}	4.41**
	Feedlots (F)	3	0.48×10^{3}	1.61×10^{2}	5.55**
	Sites (S)	2	0.17×10^{3}	0.83×10^{2}	2.86
	DF	33	0.93×10^{3}	0.28×10^{2}	0.97
	DS	22	0.53×10^{3}	0.24×10^{2}	0.83
	FS	6	0.29×10^{3}	0.49×10^{2}	1.69
	DFS	66	1.90×10^{3}	0.29×10^{2}	
	Total	143	5.71×10^{3}		
Turbidity	Dates (D)	11	7.46×10^{3}	6.78×10^{2}	6.11**
	Feedlots (F)	3	2.11×10^{3}	7.03×10^{2}	6.33**
	Sites (S)	2	0.83×10^{3}	4.14×10^{2}	3.73*
	DF	33	3.35×10^{3}	1.02×10^{2}	0.92
	DS	22	2.22×10^{3}	1.01×10^{2}	0.91
	FS	6	0.65×10^{3}	1.08×10^{2}	0.98
	DFS	66	7.35×10^{3}	1.11×10^{2}	
	Total	143	23.97×10^{3}		
Total Coliform	Dates (D)	11	6.73×10^{10}	6.12×10^{9}	1.03
	Feedlots (F)	3	1.79×10^{10}	5.98×10^{9}	1.00
	Sites (S)	2	1.36×10^{10}	6.79×10^{9}	1.14
	DF	33	21.93×10^{10}	6.64×10^{9}	1.11
	DS	22	12.94×10^{10}	5.88×10^{9}	0.98
	FS	6	3.52×10^{10}	5.87×10^{9}	0.98
	DFS	66	39.39×10^{10}	5.97×10^{9}	
	Total	143	87.67×10^{10}		
Fecal Coliform	Dates (D)	11	3.12×10^{9}	2.83×10^{8}	1.00
	Feedlots (F)	3	0.42×10^{9}	1.40×10^{8}	0.49
	Sites (S)	2	0.73×10^{9}	3.64×10^{8}	1.28
	DF	33	10.16×10^{9}	3.08×10^{8}	1.08
	DS	22	6.82×10^{9}	3.10×10^{8}	1.09
	FS	6	2.31×10^{9}	3.85×10^{8}	1.36
	DFS	66	18.75×10^{9}	2.84×10^{8}	
	Total	143	42.31×10^{9}		

Table D1. Continued

Water Quality Parameter	Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F
Fecal Streptococcus	Dates (D)	11	6.34×10^{8}	5.76×10^{7}	1.60
	Feedlots (F)	3	1.11×10^{8}	3.72×10^{7}	1.04
	Sites (S)	2	2.55×10^{8}	12.73×10^{7}	3.55*
	DF	33	12.97×10^{8}	3.93×10^{7}	1.09
	DS	22	11.45×10^{8}	5.20×10^{7}	1.45
	FS	6	3.07×10^{8}	5.11×10^{7}	1.42
	DFS	66	23.67×10^{8}	3.59×10^{7}	
	Total	143	61.16×10^{8}		

* Significant at the five percent level

** Significant at the one percent level

Table D2. WATER QUALITY PARAMETER MEANS FOR WATER SAMPLING DATES

Date	Temp. (°C)	Dissolved Oxygen (ppm)	Biochemical Oxygen Demand (ppm)	Chemical Oxygen Demand (ppm)	Kjeldahl Nitrogen (ppm)	Nitrate Nitrogen NO_3-N (ppm)
04 07 71	7.0	10.68	8.4	65.3	2.3	0.15
04 28 71	8.7	9.42	6.8	32.1	2.0	0.13
04 29 71	9.3	10.02	5.0	28.6	1.8	0.13
05 19 71	14.1	7.51	6.3	30.6	1.6	0.12
05 26 71	14.1	8.59	5.4	33.9	1.8	0.08
06 11 71	23.1	7.41	3.4	40.4	2.2	0.11
07 02 71	24.6	7.08	5.3	38.3	2.3	0.12
07 20 71	24.5	8.40	8.4	39.9	2.4	0.12
08 09 71	24.5	7.61	7.2	42.7	2.3	0.12
08 19 71	24.0	6.54	4.6	43.8	2.1	0.12
09 01 71	22.4	7.13	3.6	38.8	2.0	0.12
09 23 71	12.7	8.69	2.6	40.6	1.6	0.07
10 14 71	10.7	8.67	4.5	41.6	1.5	0.11
11 03 71	4.2	10.08	2.1	28.6	1.4	0.14

Table D2. Continued

Date	Total Phosphates (ppm)	Total Solids (ppm)	Total Volatile Solids (ppm)	Total Suspended Solids (ppm)	Total Volatile Suspended Solids (ppm)	pH
04 07 71	1.31	629	146	30	10	8.66
04 28 71	1.22	717	331	32	9	8.28
04 29 71	1.16	693	178	26	9	8.41
05 19 71	1.38	810	213	46	9	8.22
05 26 71	1.33	858	146	32	11	8.33
06 11 71	2.14	963	218	42	5	8.23
07 02 71	2.04	920	197	57	9	8.41
07 20 71	3.00	864	252	52	9	8.25
08 09 71	1.50	747	163	52	13	8.55
08 19 71	1.43	719	180	85	16	8.36
09 01 71	1.22	777	157	83	15	8.53
09 23 71	0.78	740	220	46	11	8.64
10 14 71	1.23	771	156	62	13	8.68
11 03 71	1.50	727	168	19	6	8.63

Table D2. Continued

Date	Conductivity (micromhos/cm^2 @ 25^oC)	Turbidity (ppm of SiO_3)	Total Coliform (MPN)	Fecal Coliform (MPN)	Fecal Streptococcus (MPN)
04 07 71	931	16	0	0	0
04 28 71	995	27	11807	10357	907
04 29 71	1003	24	1544	1281	125
05 19 71	1146	31	1170	187	174
05 26 71	1204	27	1214	297	133
06 11 71	1197	29	68836	1959	6689
07 02 71	1294	39	3506	2312	1448
07 20 71	1188	33	1521	512	163
08 09 71	1106	35	1523	1450	204
08 19 71	1073	42	12683	12463	1809
09 01 71	1124	47	1589	1074	1880
09 23 71	1087	33	1487	290	187
10 14 71	1074	39	8	1	0
11 03 71	1053	23	0	0	0

Table D3. WATER QUALITY PARAMETER MEANS FOR WATER SAMPLING SITES

Sampling Site	Temp. (^oC)	Dissolved Oxygen (ppm)	Biochemical Oxygen Demand (ppm)	Chemical Oxygen Demand (ppm)	Kjeldahl Nitrogen (ppm)	Nitrate Nitrogen NO_3-N (ppm)
1	16.6	7.83	4.4	38.8	1.8	0.08
2	14.7	8.84	5.8	44.2	2.0	0.09
3	14.8	8.78	5.5	40.2	2.0	0.09
4	15.1	8.66	5.2	42.8	2.0	0.12
5	16.0	8.33	4.6	42.9	1.9	0.08
6	14.6	8.58	3.9	31.4	1.5	0.28
7	16.1	8.30	5.2	39.5	2.0	0.09
8	16.4	7.91	4.5	35.9	2.0	0.13
9	16.4	8.32	5.3	37.3	1.9	0.09
10	16.6	8.11	5.7	38.7	2.0	0.16
11	17.5	7.63	5.1	34.6	1.9	0.11
12	18.5	9.87	8.4	41.5	2.4	0.11
13	16.3	7.91	4.6	35.8	1.9	0.11
14	16.6	8.30	5.1	35.4	1.9	0.09

Table D3. Continued

Sampling Site	Total Phosphates (ppm)	Total Solids (ppm)	Total Volatile Solids (ppm)	Total Suspended Solids (ppm)	Total Volatile Suspended Solids (ppm)	pH
1	1.11	808	183	30	8	8.45
2	1.29	796	175	55	12	8.48
3	1.33	811	233	50	13	8.45
4	1.44	832	213	53	13	8.45
5	1.52	766	195	27	7	8.51
6	1.81	793	188	38	9	8.31
7	1.39	751	182	33	8	8.52
8	1.53	758	203	43	10	8.47
9	1.60	757	187	36	9	8.52
10	1.45	781	187	107	16	8.43
11	1.81	791	192	39	8	8.42
12	1.48	781	199	39	13	8.32
13	1.74	773	194	66	12	8.42
14	1.79	771	207	46	10	8.40

Table D3. Continued

Sampling Site	Conductivity (micromhos/cm^2 @ 25^{o}C)	Turbidity (ppm of SiO_2)	Total Coliform (MPN)	Fecal Coliform (MPN)	Fecal Streptococcus (MPN)
1	1156	31	549	159	148
2	1127	37	1243	1005	173
3	1135	36	2465	1542	184
4	1129	39	394	151	67
5	1110	26	501	219	192
6	1114	28	15927	15027	5755
7	1070	29	586	250	101
8	1080	34	12714	12091	1923
9	1094	28	1212	691	448
10	1105	37	463	159	59
11	1119	30	79681	787	420
12	1118	25	8188	5277	6287
13	1076	35	489	111	197
14	1081	32	270	77	54

Table D4-1. CORRELATION COEFFICIENTS FOR FILM DENSITIES AND WATER QUALITY PARAMETERS FOR APRIL 7, 1971

Water Quality Parameters	B&W Green Filter #58[1]	B&W Blue Filter #47B[1]	Color IR Total	Color IR Infrared Sensitive Layer	Color IR Red Sensitive Layer
Temperature	-.440	-.300	.461	.655*	.431
Kjeldahl Nitrogen	-.204	-.633	.494	.449	.465
Biochem. Oxygen Dem	-.001	-.417	.304	.344	.252
Chem Oxygen Dem	.198	.053	-.007	-.067	-.032
Dissolved Oxygen	.576	.211	-.453	-.325	-.459
Nitrate Nitrogen	.273	.552	-.575	-.754**	-.498
Total Phosphates	-.153	-.242	.315	.256	.289
pH	-.011	-.326	.225	.355	.201
Conductivity	.254	.146	-.256	-.337	-.276
Total Solids	.139	.227	-.281	-.364	-.296
Total Vol Solids	.251	.304	-.494	-.597	-.440
Susp Solids	-.378	-.325	.322	.312	.303
Vol Susp Solids	-.199	-.194	.088	.015	.079
Turbidity	-.462	-.596	.481	.424	.467

Table D4-1. Continued

Water Quality Parameters	Color IR Green Sensitive Layer	Color Total	Color Red Layer	Color Green Layer	Color Blue Layer
Temperature	.402	.342	.310	.353	.328
Kjeldahl Nitrogen	.347	.365	.456	.342	.235
Biochem Oxygen Dem	.152	.150	.216	.143	.133
Chem Oxygen Dem	-.104	-.035	.010	-.038	-.063
Dissolved Oxygen	-.542	-.547	-.482	-.543	-.570
Nitrate Nitrogen	-.395	-.417	-.440	-.429	-.462
Total Phosphates	.269	.213	.237	.198	.182
pH	.079	.112	.187	.104	.033
Conductivity	-.244	-.175	-.205	-.160	-.038
Total Solids	-.233	-.105	-.177	-.070	.073
Total Vol Solids	-.381	-.385	-.380	-.390	-.412
Susp Solids	.272	.438	.411	.468	.460
Vol Susp Solids	.059	.287	.262	.329	.336
Turbidity	.414	.530	.540	.546	.476

* Significantly different from zero at the five percent level
** Significantly different from zero at the one percent level

[1] Correlations for the negative type black and white films have opposite signs from the positive type color films.

Table D4-2. CORRELATION COEFFICIENTS FOR FILM DENSITIES AND WATER QUALITY PARAMETERS FOR APRIL 29, 1971

Water Quality Parameters	B&W Green Filter #58[1]	B&W Blue Filter #47B[1]	Color IR Total	Color IR Infrared Sensitive Layer	Color IR Red Sensitive Layer
Temperature	-.129	-.189	.642*	.757**	.661*
Kjeldahl Nitrogen	-.681**	-.727*	.619*	.538*	.571*
Biochem Oxygen Dem	-.590*	-.555*	.152	-.042	.094
Chem Oxygen Dem	-.773**	-.540*	.369	.188	.291
Dissolved Oxygen	.093	.084	-.433	-.572*	-.440
Nitrate Nitrogen	.273	.165	-.302	-.299	-.314
Total Phosphates	-.025	-.071	.121	.034	.131
pH	-.172	.076	.007	.102	-.063
Conductivity	.251	.515	-.352	-.407	-.408
Total Solids	.317	.536*	-.391	-.427	-.445
Total Vol Solids	-.225	.114	.191	.162	.125
Susp Solids	-.244	-.369	.196	.237	.194
Vol Susp Solids	-.310	-.453	.070	.044	.019
Turbidity	-.084	-.307	.003	.175	.000
Total Coliform	-.177	-.272	-.073	-.637	-.120
Fecal Coliform	-.174	-.268	-.132	-.133	-.174
Fecal Strep	-.068	-.164	-.188	-.174	-.215

Table D4-2. Continued

Water Quality Parameters	Color IR Green Sensitive Layer	Color Total	Color Red Layer	Color Green Layer	Color Blue Layer
Temperature	.720**	.725**	.723**	.726**	.730**
Kjeldahl Nitrogen	.486	.452	.460	.441	.403
Biochem Oxygen Dem	-.022	-.046	-.039	-.067	-.117
Chem Oxygen Dem	.061	.039	.075	.009	-.075
Dissolved Oxygen	-.438	-.425	-.427	-.433	-.457
Nitrate Nitrogen	-.180	-.232	.259	-.210	-.179
Total Phosphates	.077	.062	.088	.044	.013
pH	-.137	-.094	-.084	-.095	-.079
Conductivity	-.424	-.468	-.422	-.490	-.526
Total Solids	-.438	-.468	-.427	-.486	-.513
Total Vol Solids	.105	.078	.110	.067	.043
Susp Solids	.255	.325	.282	.351	.383
Vol Susp Solids	.062	.080	.048	.090	.103
Turbidity	.099	.090	.043	.119	.158
Total Coliform	-.179	-.135	-.150	-.134	-.115
Fecal Coliform	-.240	-.196	-.212	-.195	-.175
Fecal Strep	-.250	-.193	-.212	-.187	-.158

* Significantly different from zero at the five percent level

** Significantly different from zero at the one percent level

[1] Correlations for the negative type black and white films have opposite signs from the positive type color films.

Table D4-3. CORRELATION COEFFICIENTS FOR FILM DENSITIES AND WATER QUALITY PARAMETERS FOR MAY 26, 1971

Water Quality Parameters	B&W Green Filter #58[1]	B&W Blue Filter #47B[1]	Color IR Total	Color IR Infrared Sensitive Layer	Color IR Red Sensitive Layer
Temperature	-.648	.666*	-.204	-.151	-.242
Kjeldahl Nitrogen	-.355	.444	-.318	-.225	-.341
Biochem Oxygen Dem	-.268	.355	-.082	-.344	-.016
Chem Oxygen Dem	-.174	.377	-.173	-.362	-.119
Dissolved Oxygen	-.013	-.393	.433	.136	.496
Nitrate Nitrogen	-.251	.705**	-.154	.218	-.282
Total Phosphates	-.238	.500	-.079	.382	-.219
pH	.251	-.552*	.181	.182	.190
Conductivity	-.570*	.045	-.038	-.167	-.003
Total Solids	-.583*	.209	-.117	-.224	-.102
Total Vol Solids	-.624*	.105	-.351	-.363	-.340
Susp Solids	-.309	.648*	-.127	.141	-.211
Vol Susp Solids	-.390	.377	-.110	-.162	-.093
Turbidity	-.219	.590*	-.161	.268	-.263
Total Coliform	-.328	-.066	.599*	.403	.617*
Fecal Coliform	.093	-.328	.278	.149	.298
Fecal Strep	-.342	.246	.360	.236	.343

Table D4-3. Continued

Water Quality Parameters	Color IR Green Sensitive Layer	Color Total	Color Red Layer	Color Green Layer	Color Blue Layer
Temperature	-.317	-.604*	-.613*	-.660*	-.498
Kjeldahl Nitrogen	-.428	-.477	-.491	-.490	-.293
Biochem Oxygen Dem	-.119	-.179	-.276	-.217	.000
Chem Oxygen Dem	-.254	-.268	-.343	-.301	-.069
Dissolved Oxygen	.488	.515	.494	.455	.525
Nitrate Nitrogen	-.397	-.619*	-.621*	-.618*	-.573*
Total Phosphates	-.238	-.505	-.453	-.504	-.589*
pH	.292	.464	.483	.487	.359
Conductivity	.051	.001	.033	-.097	.030
Total Solids	-.103	-.196	-.183	-.265	-.131
Total Vol Solids	-.204	-.198	-.202	-.233	-.145
Susp Solids	-.344	-.525	-.579*	-.580*	-.414
Vol Susp Solids	-.176	-.120	-.251	-.169	.140
Turbidity	-.313	-.515	-.509	-.555*	-.564*
Total Coliform	.593*	.289	.314	.216	.265
Fecal Coliform	.335	.295	.361	.306	.169
Fecal Strep	.258	-.098	-.095	-.128	-.049

* Significantly different from zero at the five percent level

** Significantly different from zero at the one percent level

[1] Correlations for the negative type black and white films have opposite signs from the positive type color films.

Table D4-4. CORRELATION COEFFICIENTS FOR FILM DENSITIES AND WATER QUALITY PARAMETERS FOR JUNE 11, 1971

Water Quality Parameters	B&W Green Filter #58[1]	B&W Blue Filter #47B[1]	Color IR Total	Color IR Infrared Sensitive Layer	Color IR Red Sensitive Layer
Temperature	-.471	-.466	.496	.450	.496
Kjeldahl Nitrogen	-.654*	-.746**	.737**	.708**	.734**
Biochem Oxygen Dem	-.728**	-.783**	.712**	.634*	.716**
Chem Oxygen Dem	-.461	-.354	.383	.208	.425
Dissolved Oxygen	-.519	-.417	.558*	.451	.578*
Nitrate Nitrogen	-.184	-.234	.116	.060	.123
Total Phosphates	-.444	-.345	.321	.293	.327
pH	.119	.175	-.108	-.097	-.106
Conductivity	-.750**	-.777**	.850**	.845**	.843**
Total Solids	-.528	-.555*	.578*	.651*	.551
Total Vol Solids	-.673**	-.686**	.723**	.731**	.711**
Susp Solids	.217	.053	-.152	-.040	-.182
Vol Susp Solids	.422	.269	-.406	-.357	-.413
Turbidity	.546*	.455	-.506	-.406	-.528
Total Coliform	-.662**	-.670**	.631*	.455	.669**
Fecal Coliform	-.443	-.479	.447	.383	.450
Fecal Strep	-.386	-.428	.393	.350	.392

Table D4-4. Continued

Water Quality Parameters	Color IR Green Sensitive Layer	Color Total	Color Red Layer	Color Green Layer	Color Blue Layer
Temperature	.519	.188	.149	.171	.118
Kjeldahl Nitrogen	.722**	.456	.468	.450	.461
Biochem Oxygen Dem	.729**	.635*	.631*	.644*	.628*
Chem Oxygen Dem	.437	.724**	.752**	.712**	.582*
Dissolved Oxygen	.557*	.623*	.660*	.592*	.400
Nitrate Nitrogen	.176	-.048	-.099	-.028	.029
Total Phosphates	.362	.093	.067	.104	-.015
pH	-.135	.192	.228	.183	.102
Conductivity	.826**	.347	.358	.336	.215
Total Solids	.525	.260	.275	.246	.236
Total Vol Solids	.695**	.272	.282	.275	.157
Susp Solids	-.201	-.264	-.259	-.242	-.061
Vol Susp Solids	-.420	-.087	-.071	-.070	.151
Turbidity	-.544*	-.498	-.501	-.485	-.307
Total Coliform	.696**	.690**	.718**	.688*	.616*
Fecal Coliform	.477	.304	.273	.295	.326
Fecal Strep	.417	.231	.195	.222	.268

* Significantly different from zero at the five percent level

** Significantly different from zero at the one percent level

[1] Correlations for the negative type black and white films have opposite signs from the positive type color films.

Table D4-5. CORRELATION COEFFICIENTS FOR FILM DENSITIES AND WATER QUALITY PARAMETERS FOR JULY 20, 1971

Water Quality Parameters	B&W Green Filter #58[1]	B&W Blue Filter #47B[1]	Color IR Total	Color IR Infrared Sensitive Layer	Color IR Red Sensitive Layer
Temperature	.713**	.723**	.633*	.553*	.640*
Kjeldahl Nitrogen	-.389	-.299	-.202	-.143	-.210
Biochem Oxygen Dem	-.138	-.040	.040	.180	-.026
Chem Oxygen Dem	-.288	-.243	.047	-.050	-.047
Dissolved Oxygen	.451	.485	.532	.393	.590*
Nitrate Nitrogen	-.131	-.061	-.210	.041	-.330
Total Phosphates	-.276	-.296	-.416	-.213	-.500
pH	-.117	-.110	.330	.224	.379
Conductivity	-.069	-.192	-.582*	-.763**	-.471
Total Solids	-.157	-.267	-.781**	-.847**	-.713**
Total Vol Solids	-.256	-.291	-.518	-.481	-.509
Susp Solids	-.098	-.059	-.452	-.239	-.547*
Vol Susp Solids	.247	.281	-.510	-.378	-.559*
Turbidity	-.259	-.307	-.788**	-.640*	-.840**
Total Coliform	.579	.481	.152	-.017	.227
Fecal Coliform	.148	.076	.076	.030	.100
Fecal Strep	-.348	-.412	.299	.233	.318

Table D4-5. Continued

Water Quality Parameters	Color IR Green Sensitive Layer	Color Total	Color Red Layer	Color Green Layer	Color Blue Layer
Temperature	.595*	.494	.501	.474	.543*
Kjeldahl Nitrogen	-.214	-.306	-.311	-.317	-.381
Biochem Oxygen Dem	-.044	-.222	-.238	-.239	-.245
Chem Oxygen Dem	-.100	-.280	-.248	-.278	-.432
Dissolved Oxygen	.611*	.666**	.673**	.645*	.630*
Nitrate Nitrogen	-.367	-.448	-.463	-.413	-.382
Total Phosphates	-.533*	-.595*	-.652*	-.562*	-.523
pH	.399	.548*	.540*	.572*	.353
Conductivity	-.405	.106	.132	.093	.166
Total Solids	-.613*	-.049	-.040	-.051	.108
Total Vol Solids	-.371	-.199	-.153	-.197	-.061
Susp Solids	-.600*	-.384	-.410	-.346	-.316
Vol Susp Solids	-.615	-.226	-.272	-.219	-.132
Turbidity	-.816**	-.479	-.494	-.469	-.319
Total Coliform	.335	.634*	.682**	.625*	.755**
Fecal Coliform	.210	.117	.150	.129	.148
Fecal Strep	.352	.058	.074	.061	-.039

* Significantly different from zero at the five percent level

** Significantly different from zero at the one percent level

[1] Correlations for the negative type black and white films have opposite signs from the positive type color films.

Table D4-6. CORRELATION COEFFICIENTS FOR FILM DENSITIES AND WATER QUALITY PARAMETERS FOR AUGUST 9, 1971

Water Quality Parameters	B&W Green Filter #58[1]	B&W Blue Filter #47B[1]	Color IR Total	Color IR Infrared Sensitive Layer	Color IR Red Sensitive Layer
Temperature	.666**	.525	.086	-.032	.114
Kjeldahl Nitrogen	.110	.025	-.435	-.272	-.475
Biochem Oxygen Dem	.462	.441	.008	-.045	-.003
Chem Oxygen Dem	-.655*	-.664**	-.031	.194	-.100
Dissolved Oxygen	.575*	.392	-.180	-.234	-.149
Nitrate Nitrogen	-.054	-.102	-.487	-.552*	-.407
Total Phosphates	.358	.274	-.335	-.305	-.350
pH	.187	.004	-.415	-.406	-.386
Conductivity	-.544*	-.545*	-.023	-.125	.038
Total Solids	-.609*	-.545*	-.038	-.127	.018
Total Vol Solids	.087	.153	.176	-.042	.259
Susp Solids	-.386	-.460	-.279	-.016	-.343
Vol Susp Solids	-.349	-.481	-.464	-.239	-.499
Turbidity	-.292	-.236	-.224	-.204	-.196
Total Coliform	.504	.235	-.205	-.230	-.168
Fecal Coliform	.503	.235	-.205	-.230	-.169
Fecal Strep	.257	.235	-.167	-.323	-.080

Table D4-6. Continued

Water Quality Parameters	Color IR Green Sensitive Layer	Color Total	Color Red Layer	Color Green Layer	Color Blue Layer
Temperature	-.079	-.482	-.548*	-.416	-.377
Kjeldahl Nitrogen	-.265	-.302	-.241	-.321	-.272
Biochem Oxygen Dem	.043	-.480	-.535*	-.379	-.377
Chem Oxygen Dem	.039	.596*	.659*	.545*	.553*
Dissolved Oxygen	-.441	-.377	-.321	-.423	-.319
Nitrate Nitrogen	-.407	.065	.160	-.042	.074
Total Phosphates	-.051	-.189	-.288	-.092	-.015
pH	-.546*	.197	.320	.052	.136
Conductivity	-.036	.493	.653*	.334	.251
Total Solids	.024	.544*	.682**	.394	.283
Total Vol Solids	.251	.158	.108	.141	.024
Susp Solids	-.130	.491	.498	.448	.535*
Vol Susp Solids	-.377	.410	.540*	.274	.378
Turbidity	-.024	.192	.242	.122	.137
Total Coliform	-.490	-.337	-.250	-.403	-.286
Fecal Coliform	-.486	-.324	-.237	-.390	-.275
Fecal Strep	-.213	-.702**	-.579*	-.757**	-.646*

* Significantly different from zero at the five percent level

** Significantly different from zero at the one percent level

[1] Correlations for the negative type black and white films have opposite signs from the positive type color films.

Table D4-7. CORRELATION COEFFICIENTS FOR FILM DENSITIES AND WATER QUALITY PARAMETERS FOR AUGUST 19, 1971

Water Quality Parameters	B&W Green Filter #58[1]	B&W Blue Filter #47B[1]	Color IR Total	Color IR Infrared Sensitive Layer	Color IR Red Sensitive Layer
Temperature	.695**	.446	-.506	-.625*	-.404
Kjeldahl Nitrogen	-.238	-.085	.326	.320	.314
Biochem Oxygen Dem	-.331	-.377	.405	.232	.452
Chem Oxygen Dem	-.227	-.311	.420	.412	.418
Dissolved Oxygen	.418	.124	.022	-.234	.157
Nitrate Nitrogen	-.448	-.311	.129	.290	.032
Total Phospahtes	-.508	-.493	.181	.272	.104
pH	.533*	.436	-.378	-.434	-.308
Conductivity	.449	.548*	-.226	-.231	-.181
Total Solids	.389	.584*	-.237	-.192	-.213
Total Vol Solids	.283	.188	-.119	-.262	-.041
Susp Solids	.095	.091	-.125	.024	-.164
Vol Susp Solids	-.085	-.110	.109	.206	.075
Turbidity	-.249	-.103	.094	.233	.023
Total Coliform	-.501	-.455	.238	.275	.179
Fecal Coliform	-.498	-.454	.239	.271	.182
Fecal Strep	-.499	-.460	.206	.254	.142

Table D4-7. Continued

Water Quality Parameters	Color IR Green Sensitive Layer	Color Total	Color Red Layer	Color Green Layer	Color Blue Layer
Temperature	-.602*	-.541*	-.449	-.572*	-.414
Kjeldahl Nitrogen	.409	.263	.242	.255	.163
Biochem Oxygen Dem	.532*	.435	.475	.398	.391
Chem Oxygen Dem	.371	.437	.455	.405	.416
Dissolved Oxygen	-.142	-.160	.016	-.253	-.117
Nitrate Nitrogen	.354	.350	.204	.431	.380
Total Phosphates	.461	.408	.294	.476	.501
pH	-.594*	-.446	-.354	-.481	-.413
Conductivity	-.508	-.456	-.368	-.511	-.561*
Total Solids	-.480	-.430	-.375	-.470	-.550*
Total Vol Solids	-.127	-.124	-.051	-.162	-.088
Susp Solids	-.142	.033	-.045	.071	.119
Vol Susp Solids	.116	.232	.173	.256	.304
Turbidity	.214	.255	.143	.309	.233
Total Coliform	.519	.422	.333	.481	.451
Fecal Coliform	.518	.420	.332	.478	.448
Fecal Strep	.491	.417	.310	.484	.455

* Significantly different from zero at the five percent level

** Significantly different from zero at the one percent level

[1] Correlations for the negative type black and white films have opposite signs from the positive type color films.

Table D4-8. CORRELATION COEFFICIENTS FOR FILM DENSITIES AND WATER QUALITY PARAMETERS FOR SEPTEMBER 1, 1971

Water Quality Parameters	B&W Green Filter #58[1]	B&W Blue Filter #47B[1]	Color IR Total	Color IR Infrared Sensitive Layer	Color IR Red Sensitive Layer
Temperature	-.159	-.397	.338	.256	.373
Kjeldahl Nitrogen	-.124	-.452	.128	-.025	.214
Biochem Oxygen Dem	-.118	-.396	.144	.013	.214
Chem Oxygen Dem	-.048	-.015	.201	.258	.182
Dissolved Oxygen	-.142	-.427	.119	-.010	.200
Nitrate Nitrogen	.007	-.133	-.214	-.241	-.177
Total Phosphates	.003	-.101	-.015	-.015	-.023
pH	-.498	-.597*	.181	.069	.257
Conductivity	.098	.123	-.314	-.236	-.332
Total Solids	.079	.020	-.355	-.321	-.339
Total Vol Solids	-.487	-.417	.261	.276	.244
Susp Solids	-.250	-.314	.128	.028	.172
Vol Susp Solids	-.265	-.351	.171	.059	.227
Turbidity	-.293	.062	-.452	-.519	-.390
Total Coliform	-.146	-.462	.121	.044	.185
Fecal Coliform	-.136	-.443	.132	.073	.187
Fecal Strep	.024	-.220	-.116	-.105	-.105

Table D4-8. Continued

Water Quality Parameters	Color IR Green Sensitive Layer	Color Total	Color Red Layer	Color Green Layer	Color Blue Layer
Temperature	.341	.055	-.038	-.001	-.006
Kjeldahl Nitrogen	.213	.083	.001	.016	-.058
Biochem Oxygen Dem	.177	.196	.183	.105	.240
Chem Oxygen Dem	.201	-.002	.005	.040	-.045
Dissolved Oxygen	.169	.158	.164	.080	.222
Nitrate Nitrogen	-.125	.196	.258	.230	.199
Total Phosphates	.013	.287	.337	.325	.347
pH	.193	.409	.416	.377	.433
Conductivity	-.348	-.030	.075	-.012	.100
Total Solids	-.319	-.010	.086	.018	.051
Total Vol Solids	.165	.420	.448	.403	.449
Susp Solids	.228	.537*	.572*	.558*	.556*
Vol Susp Solids	.281	.553*	.594*	.565*	.618*
Turbidity	-.317	-.073	.010	-.070	.010
Total Coliform	.110	.021	-.018	-.071	-.011
Fecal Coliform	.115	.010	-.035	-.075	.050
Fecal Strep	-.089	.032	.033	.056	.070

* Significantly different from zero at the five percent level

** Significantly different from zero at the one percent level

[1] Correlations for the negative type black and white films have opposite signs from the positive type color films.

Table D4-9. CORRELATION COEFFICIENTS FOR FILM DENSITIES AND WATER QUALITY PARAMETERS FOR NOVEMBER 3, 1971

Water Quality Parameters	B&W Green Filter #58[1]	B&W Blue Filter #47B[1]	Color IR Total	Color IR Infrared Sensitive Layer	Color IR Red Sensitive Layer	Color IR Green Sensitive Layer
Temperature	.106	-.142	-.280	-.425	-.203	-.361
Kjeldahl Nitrogen	.201	.163	-.691**	-.212	-.497	-.114
Biochem Oxygen Dem	.377	.174	-.706**	-.366	-.549*	-.285
Chem Oxygen Dem	.301	.162	-.585**	-.331	-.480	-.280
Dissolved Oxygen	-.285	-.058	.468	.334	.344	.226
Nitrate Nitrogen	.009	.198	-.009	.044	.045	.125
Total Phosphates	.466	-.041	-.783**	-.286	-.650*	-.249
pH	-.256	-.339	.329	.434	.192	.312
Conductivity	.025	.293	-.204	.116	-.148	.118
Total Solids	.175	.175	-.062	-.176	.074	-.183
Total Vol Solids	-.110	.111	-.132	.007	.013	.113
Susp Solids	.353	.300	-.563*	-.236	-.566*	-.235
Vol Susp Solids	.071	.181	-.506	-.109	-.437	-.021
Turbidity	.204	.027	-.121	.063	-.352	-.084

* Significantly different from zero at the five percent level

** Significantly different from zero at the one percent level

[1] Correlations for the negative type black and white films have opposite signs from the positive type color films.

Table D5. LINEAR REGRESSION EQUATIONS FOR NINE AERIAL MISSIONS COMBINED[1]

Film-Filter Combination	Temperature	Kjeldahl Nitrogen	Biochemical Oxygen Demand
Density B&W #58 Green	$Y=18.55X - 1.92$ (1.56)	$Y=0.12X + 1.90$ (0.14)	$Y=-0.87X + 6.17$ (0.84)
Density B&W #47B Blue	$Y=-6.93X + 23.1$ (2.35)	$Y=0.11X + 1.93$ (0.15)	$Y=1.59X + 3.92$ (0.89)
Density Color IR Total	$Y=-6.92X + 28.6$ (1.41)	$Y=-0.18X + 2.31$ (0.10)	$Y=-0.34X + 5.83$ (0.57)
Density Color IR Infrared	$Y=-10.97X + 42.2$ (1.76)	$Y=-0.05X + 2.14$ (0.13)	$Y=1.11X + 2.71$ (0.74)
Density Color IR Red	$Y=-6.12X + 25.8$ (1.37)	$Y=-0.16X + 2.22$ (0.09)	$Y=-0.52X + 5.99$ (0.55)
Density Color IR Green	$Y=-3.87X + 22.9$ (0.98)	$Y=-0.09X + 2.16$ (0.06)	$Y=-0.26X + 5.65$ (0.38)
Density Color Total	$Y=-7.94X + 27.1$ (2.67)	$Y=-0.24X + 1.86$ (0.16)	$Y=1.03X + 4.61$ (1.14)
Density Color Red	$Y=-9.71X + 31.5$ (2.37)	$Y=0.23X + 1.81$ (0.14)	$Y=1.05X + 4.31$ (1.05)
Density Color Green	$Y=-6.30X + 25.3$ (2.48)	$Y=-0.18X + 1.92$ (0.14)	$Y=0.63X + 5.03$ (1.05)
Density Color Blue	$Y=-5.42X + 24.3$ (2.49)	$Y=-0.04X + 2.07$ (0.15)	$Y=-.43X + 5.24$ (1.05)

---

[1] Standard error of regression coefficients are given in parentheses under the coefficient.

X is film fensity reading

Y is water quality parameter

Table D5. Continued

Film-Filter Combination	Chemical Oxygen Demand	Dissolved Oxygen	Nitrate Nitrogen
Density B&W #58 Green	Y=-7.98X + 47.8 (4.86)	Y=-3.19X + 11.7 (0.50)	Y=-0.02X + 0.14 (0.03)
Density B&W #47B Blue	Y=13.36X + 28.2 (5.07)	Y=1.32X + 7.33 (0.61)	Y=0.03X + 0.10 (0.03)
Density Color IR Total	Y=-0.86X + 41.0 (3.30)	Y=1.41X + 6.14 (0.37)	Y=-0.001X + 0.12 (0.02)
Density Color IR Infrared	Y=0.60X + 38.2 (4.33)	Y=2.31X + 3.18 (0.47)	Y=0.03X + 0.18 (0.02)
Density Color IR Red	Y=-0.77X + 40.6 (3.17)	Y=1.24X + 6.72 (0.36)	Y=0.00X + 0.12 (0.02)
Density Color IR Green	Y=-0.47X + 40.2 (2.23)	Y=-.74X + 7.37 (0.26)	Y=0.01X + 0.11 (0.01)
Density Color Total	Y=1.05X + 39.9 (7.10)	Y=2.10X + 6.07 (0.79)	Y=-0.05X + 0.75 (0.03)
Density Color Red	Y=4.85X + 34.7 (6.49)	Y=2.40X + 5.12 (0.71)	Y=-0.05X + 0.18 (0.03)
Density Color Green	Y=-1.02X + 42.1 (6.51)	Y=1.58X + 6.63 (0.73)	Y=-0.05X + 0.17 (0.03)
Density Color Blue	Y=-6.44X + 47.4 (6.47)	Y=1.20X + 7.05 (0.74)	Y=-0.06X + 0.18 (0.03)

Table D5. Continued

Film-Filter Combination	Total Phosphates	pH	Conductivity
Density B&W #58 Green	Y=0.12X + 1.51 (0.23)	Y=-0.16X + 8.60 (0.06)	Y=89.60X + 1008.9 (39.14)
Density B&W #47B Blue	Y=-0.77X + 2.29 (0.23)	Y=0.10X + 8.35 (0.07)	Y=-142.29X + 1222.3 (40.43)
Density Color IR Total	Y=0.09X + 1.48 (0.15)	Y=0.16X + 8.17 (0.04)	Y=-26.76X + 1145.3 (26.79)
Density Color IR Infrared	Y=0.13X + 1.34 (0.20)	Y=0.16X + 8.06 (0.05)	Y=-59.47X + 1237.0 (34.84)
Density Color IR Red	Y=0.08X + 1.52 (0.15)	Y=0.15X + 8.22 (0.04)	Y=-19.56X + 1128.7 (25.73)
Density Color IR Green	Y=0.11X + 1.47 (0.10)	Y=0.11X + 8.28 (0.03)	Y=-14.17X + 1122.0 (18.13)
Density Color Total	Y=0.33X + 1.31 (0.32)	Y=-0.09X + 8.50 (0.09)	Y=-0.66X + 1108.5 (59.22)
Density Color Red	Y=0.15X + 1.45 (0.30)	Y=-0.02X + 8.43 (0.08)	Y=-25.76X + 1141.2 (54.20)
Density Color Green	Y=0.36X + 1.29 (0.29)	Y=0.11X + 8.52 (0.08)	Y=16.79X + 1090.8 (54.32)
Density Color Blue	Y=0.22X + 1.43 (0.30)	Y=-0.15X + 8.56 (0.08)	Y=60.66X + 1048.0 (53.93)

Table D5. Continued

Film-Filter Combinations	Total Solids	Total Volatile Solids	Suspended Solids
Density B&W #58 Green	Y=43.43X + 733.9 (38.23)	Y=8.24X + 171.1 (18.94)	Y=52.77X - 7.4 (14.04)
Density B&W #47B Blue	Y=123.39X + 883.5 (39.24)	Y=-44.53X + 217.4 (19.71)	Y=-1.09X + 48.1 (15.75)
Density Color IR Total	Y=-31.06X + 829.6 (25.70)	Y=-8.63X + 193.7 (12.73)	Y=-24.58X + 87.3 (9.73)
Density Color IR Infrared	Y=-43.03X + 876.8 (33.67)	Y=-20.95X + 227.3 (16.61)	Y=-42.92X + 144.9 (12.49)
Density Color IR Red	Y=-23.64X +811.6 (24.70)	Y=-67.04X + 188.9 (12.21)	Y=-21.99X + 77.7 (9.36)
Density Color IR Green	Y=-19.16X + 806.5 (17.38)	Y=-2.57X + 183.3 (8.61)	Y=-13.96X + 67.3 (6.62)
Density Color Total	Y=97.55X + 685.2 (56.20)	Y=5.67X + 175.2 (28.39)	Y=-59.20X + 111.5 (21.10)
Density Color Red	Y=62.11X + 704.0 (51.86)	Y=-2.93X + 184.8 (26.02)	Y=-52.49X + 125.1 (19.24)
Density Color Green	Y=109.86X + 674.2 (51.21)	Y=7.87X + 173.1 (26.05)	Y=-52.00X + 104.3 (19.40)
Density Color Blue	Y=135.91X + 651.4 (50.52)	Y=0.22X + 180.8 (26.02)	Y=-48.68X + 98.7 (19.47)

Table D5. Continued

Film-Filter Combinations	Volatile Suspended Solids	Turbidity	Total Coliform
Density B&W #58 Green	Y=6.49X + 3.8 (1.85)	Y=23.89X + 6.3 (3.37)	Y=-134,949X + 167300 (39343)
Density B&W #47B Blue	Y=1.02X + 9.5 (2.06)	Y=-5.09X + 35.3 (4.24)	Y=-80636.1X + 79645 (41214)
Density Color IR Total	Y=-3.31X + 16.0 (1.27)	Y=-9.61X + 46.7 (2.56)	Y=99959.7X + 135544 (28850)
Density Color IR Infrared	Y=-4.97X + 21.9 (1.65)	Y=-18.85X + 73.9 (3.10)	Y=51368.9X - 99639 (29429)
Density Color IR Red	Y=-3.10X + 14.9 (1.22)	Y=-8.59X + 42.9 (2.47)	Y=113292X - 126843 (27273)
Density Color IR Green	Y=-1.92X + 13.3 (0.87)	Y=-5.10X + 38.3 (1.76)	Y=72323.1X - 75518 (19305)
Density Color Total	Y=-8.17X + 19.5 (2.69)	Y=-25.38X + 58.1 (5.22)	Y=104198X - 93251 (38317)
Density Color Red	Y=-7.62X + 21.0 (2.46)	Y=-25.39X + 64.9 (4.68)	Y=101028X - 115913 (36054)
Density Color Green	Y=-7.64X + 18.8 (2.74)	Y=-22.09X + 54.4 (4.84)	Y=91057.1X - 78838 (34849)
Density Color Blue	Y=5.61X + 16.6 (2.51)	Y=-19.08X + 50.8 (4.95)	Y=71351.9X - 57973 (34984)

Table D5. Continued

Film-Filter Combination	Fecal Coliform	Fecal Streptococcus
Density B&W #58 Green	Y=-1922X + 4921 (7207)	Y=6339X + 8834 (3348)
Density B7W #47B Blue	Y=8897X + 10105 (7212)	Y=-4094X + 4971 (3413)
Density Color IR Total	Y=808X + 1521 (5292)	Y=4162X - 4601 (2467)
Density Color IR Infrared	Y=-2298X + 7745 (5165)	Y=1774X - 2307 (2439)
Density Color IR Red	Y=1176X + 1271 (5122)	Y=4903X - 4467 (2371)
Density Color IR Green	Y=2578X - 426 (3565)	Y=3217X - 2352 (1659)
Density Color Total	Y=-3269X + 6044 (6870)	Y=4111X - 2608 (3226)
Density Color Red	Y=-3778X + 7528 (6474)	Y=3654X - 3080 (3045)
Density Color Green	Y=-2957X + 5692 (6231)	Y=3701X - 2148 (2926)
Density Color Blue	Y=-3248X + 5937 (6172)	Y =2801X - 1202 (2909)

Table D6-1. CORRELATION COEFFICIENTS FOR ADJUSTED FILM DENSITIES AND WATER QUALITY PARAMETERS FOR APRIL 7, 1971

Water Quality Parameters	B&W Green Filter #58[1]	B&W Blue Filter #47B[1]	Color IR Total	Color IR Infrared Sensitive Layer	Color IR Red Sensitive Layer
Temperature	.395	.000	.398	.593	.403
Kjeldahl Nitrogen	.148	.838**	.521	.484	.493
Biochem Oxygen Dem	-.004	.797**	.380	.432	.315
Chem Oxygen Dem	-.166	.522	.095	.043	.043
Dissolved Oxygen	-.626*	-.215	-.463	-.324	-.461
Nitrate Nitrogen	-.260	-.506	-.561	-.753**	-.498
Total Phosphates	.190	.821**	.434	.372	.384
pH	-.094	.049	.184	.334	.167
Conductivity	-.169	.163	-.206	-.282	-.244
Total Solids	-.030	-.135	-.299	-.381	-.310
Total Vol Solids	-.267	-.411	-.529	-.632*	-.471
Susp Solids	.378	-.105	.181	.176	.207
Vol Susp Solids	.215	-.413	-.097	-.201	-.046
Turbidity	.442	.223	.380	.324	.404

Table D6-1. Continued

Water Quality Parameters	Color IR Green Sensitive Layer	Color Total	Color Red Layer	Color Green Layer	Color Blue Layer
Temperature	.374	.270	.205	.331	.268
Kjeldahl Nitrogen	.371	.406	.508	.383	.200
Biochem Oxygen Dem	.201	.233	.318	.223	.180
Chem Oxygen Dem	-.012	.076	.145	.053	-.002
Dissolved Oxygen	-.574	-.560	-.499	-.583	-.633*
Nitrate Nitrogen	-.356	-.403	-.410	-.441	-.471
Total Phosphates	.367	.344	.391	.313	.257
pH	.029	.068	.140	.094	.017
Conductivity	-.183	-.125	-.129	-.112	.065
Total Solids	-.205	-.128	-.190	-.082	.112
Total Vol Solids	-.378	-.426	-.404	-.429	-.456
Susp Solids	.205	.294	.238	.368	.328
Vol Susp Solids	-.019	.122	.064	.198	.179
Turbidity	.375	.441	.427	.478	.328

* Significantly different from zero at the five percent level

** Significantly different from zero at the one percent level

[1] Correlations for the negative type black and white films have opposite signs from the positive type color films.

Table D6-2. CORRELATION COEFFICIENTS FOR ADJUSTED FILM DENSITIES AND WATER QUALITY PARAMETERS FOR APRIL 29, 1971

Water Quality Parameters	B&W Green Filter #58[1]	B&W Blue Filter #47B[1]	Color IR Total	Color IR Infrared Sensitive Layer	Color IR Red Sensitive Layer
Temperature	.512	.400	.685**	.630*	.716*
Kjeldahl Nitrogen	-.048	-.144	.048	-.072	.142
Biochem Oxygen Dem	-.233	-.344	-.313	-.433	-.262
Chem Oxygen Dem	-.447	-.538*	-.413	-.523	-.317
Dissolved Oxygen	-.139	-.099	-.309	-.332	-.353
Nitrate Nitrogen	-.251	-.083	-.190	-.130	-.241
Total Phosphates	-.256	-.172	-.097	-.137	-.046
pH	-.070	-.258	-.118	-.056	-.145
Conductivity	-.283	-.318	-.277	-.229	-.360
Total Solids	-.255	-.264	-.254	-.193	-.348
Total Vol Solids	.184	-.398	-.112	-.125	-.102
Susp Solids	.096	.035	.082	.055	.117
Vol Susp Solids	.097	.043	-.026	-.068	-.036
Turbidity	-.179	-.072	-.124	-.116	-.097
Total Coliform	-.076	-.076	-.163	-.147	-.188
Fecal Coliform	-.068	-.076	.197	-.181	-.223
Fecal Strep	-.075	-.084	-.189	-.160	-.217

Table D6-2. Continued

Water Quality Parameters	Color IR Green Sensitive Layer	Color Total	Color Red Layer	Color Green Layer	Color Blue Layer
Temperature	.727**	.698*	.687**	.711**	.701**
Kjeldahl Nitrogen	.202	.116	.066	.162	.148
Biochem Oxygen Dem	-.257	-.293	-.329	-.268	-.287
Chem Oxygen Dem	-.324	-.380	-.407	-.350	-.376
Dissolved Oxygen	-.375	-.336	-.329	-.355	-.375
Nitrate Nitrogen	-.134	-.154	-.175	-.145	-.120
Total Phosphates	-.034	-.054	-.051	-.055	-.061
pH	-.201	-.145	-.147	-.136	-.122
Conductivity	-.400	-.368	-.322	-.409	-.433
Total Solids	-.379	-.337	-.293	-.378	-.399
Total Vol Solids	-.060	-.088	-.091	-.077	-.075
Susp Solids	.206	.204	.147	.256	.276
Vol Susp Solids	.019	.014	-.037	.045	.045
Turbidity	.035	-.003	-.061	.045	.074
Total Coliform	-.210	-.171	-.196	-.154	-.140
Fecal Coliform	-.257	-.215	-.237	-.201	-.188
Fecal Strep	-.236	-.185	-.205	-.170	-.152

* Significantly different from zero at the five percent level

** Significantly different from zero at the one percent level

[1] Correlations for the negative type black and white films have opposite signs from the positive type color films.

Table D6-3. CORRELATION COEFFICIENTS FOR ADJUSTED FILM DENSITIES AND WATER QUALITY PARAMETERS FOR MAY 26, 1971

Water Quality Parameters	Green Filter #58[1]	Blue Filter #47B[1]	Color IR Total	Color IR Infrared Sensitive Layer	Color IR Red Sensitive Layer
Temperature	.710**	-.648*	.249	.330	.130
Kjeldahl Nitrogen	.471	-.390	.094	.213	-.063
Biochem Oxygen Dem	.207	-.358	-.119	-.225	-.076
Chem Oxygen Dem	.179	-.380	-.097	-.158	-.113
Dissolved Oxygen	-.147	.363	.019	-.276	.169
Nitrate Nitrogen	.433	-.686**	.407	.657*	.190
Total Phosphates	.405	-.476	.449	.728**	.254
pH	-.314	.565*	-.112	-.161	-.047
Conductivity	.508	-.057	.073	.007	.085
Total Solids	.576*	-.231	.100	.061	.068
Total Vol Solids	.610*	-.060	-.171	-.059	-.204
Susp Solids	.442	-.637	.255	.449	.078
Vol Susp Solids	.394	-.271	.039	.049	.013
Turbidity	.366	-.569*	.317	.616*	.126
Total Coliform	.226	.065	.525	.209	.658*
Fecal Coliform	-.135	.302	.210	.012	.305
Fecal Strep	.336	-.269	.446	.246	.502

Table D6-3. Continued

Water Quality Parameters	Color IR Green Sensitive Layer	Color Total	Color Red Layer	Color Green Layer	Color Blue Layer
Temperature	.002	-.483	-.427	-.534*	-.241
Kjeldahl Nitrogen	-.170	-.340	-.331	-.360	.003
Biochem Oxygen Dem	-.098	-.295	-.458	-.354	-.037
Chem Oxygen Dem	-.192	-.332	-.476	-.399	-.046
Dissolved Oxygen	.312	.398	.280	.307	.320
Nitrate Nitrogen	-.093	-.404	-.317	-.427	-.294
Total Phosphates	.049	-.275	-.091	-.258	-.337
pH	.117	.414	.387	.463	.229
Conductivity	.227	.118	.171	-.043	.159
Total Solids	.116	-.089	-.059	-.198	.034
Total Vol Solids	-.080	-.136	-.090	-.153	.008
Susp Solids	-.184	-.444	-.536*	-.535*	-.273
Vol Susp Solids	-.071	-.074	-.271	-.153	.274
Turbidity	-.062	-.348	-.313	-.404	-.381
Total Coliform	.671**	.341	.433	.286	.243
Fecal Coliform	.368	.347	.469	.396	.145
Fecal Strep	.352	-.081	.021	-.081	-.041

* Significantly different from zero at the five percent level

** Significantly different from zero at the one percent level

[1] Correlations for the negative type black and white films have opposite signs from the positive type color films.

Table D6-4. CORRELATION COEFFICIENTS FOR ADJUSTED FILM DENSITIES AND WATER QUALITY PARAMETERS FOR JUNE 11, 1971

Water Quality Parameters	B&W Green Filter #58[1]	B&W Blue Filter #47B[1]	Color IR Total	Color IR Infrared Sensitive Layer	Color IR Red Sensitive Layer
Temperature	.149	-.077	.157	-.419	.282
Kjeldahl Nitrogen	.483	.311	.465	-.221	.567*
Biochem Oxygen Dem	.608*	.426	.414	-.296	.533*
Chem Oxygen Dem	.592*	.181	.122	-.431	.283
Dissolved Oxygen	.528	.103	.383	-.227	.520
Nitrate Nitrogen	-.061	-.075	-.219	-.487	-.127
Total Phosphates	.406	.288	.292	-.031	.342
pH	.156	.215	.216	.424	.135
Conductivity	.628*	.394	.753**	.004	.840**
Total Solids	.449	.370	.611*	.240	.591*
Total Vol Solids	.548*	.339	.644*	.017	.712**
Susp Solids	-.264	.055	-.035	.240	-.153
Vol Susp Solids	-.291	.022	-.338	.129	-.430
Turbidity	-.588*	-.252	-.365	.193	-.490
Total Coliform	.857**	.604*	.402	-.303	.555*
Fecal Coliform	.162	.007	.056	-.467	.175
Fecal Strep	.092	-.021	.037	-.414	.135

Table D6-4. Continued

Water Quality Parameters	Color IP Green Sensitive Layer	Color Total	Color Red Layer	Color Green Layer	Color Blue Layer
Temperature	.409	-.581*	-.629*	-.584*	-.577*
Kjeldahl Nitrogen	.617*	-.525	-.549*	-.515	-.459
Biochem Oxygen Dem	.618*	-.322	-.373	-.316	-.311
Chem Oxygen Dem	.364	.055	.030	.078	-.087
Dissolved Oxygen	.515	-.143	-.160	-.121	-.308
Nitrate Nitrogen	.051	-.394	-.426	-.402	-.302
Total Phosphates	.438	-.230	-.295	-.236	-.319
pH	.010	.505	.517	.519	.380
Conductivity	.860**	-.607*	-.658*	-.607*	-.646*
Total Solids	.565*	-.323	-.342	-.315	-.262
Total Vol Solids	.717**	-.505	-.549*	-.510	-.531
Susp Solids	-.204	.002	.040	-.001	.209
Vol Susp Solids	-.466	.327	.378	.340	.504
Turbidity	-.562*	.188	.247	.180	.345
Total Coliform	.664**	-.167	-.198	-.142	-.243
Fecal Coliform	.307	-.451	-.485	-.447	-.399
Fecal Strep	.256	-.434	-.465	-.433	-.367

* Significantly different from zero at the five percent level

** Significantly different from zero at the one percent level

1 Correlations for the negative type black and white films have opposite signs from the positive type color films.

Table D6-5. CORRELATION COEFFICIENTS FOR ADJUSTED FILM DENSITIES AND WATER QUALITY PARAMETERS FOR JULY 20, 1971

Water Quality Parameters	B&W Green Filter #58[1]	B&W Blue Filter #47B[1]	Color IR Total	Color IR Infrared Sensitive Layer	Color IR Red Sensitive Layer
Temperature	-.384	-.273	.608*	.534*	.641*
Kjeldahl Nitrogen	.212	.090	-.215	-.161	-.223
Biochem Oxygen Dem	.270	.258	.155	.270	.101
Chem Oxygen Dem	.250	.173	-.052	-.054	-.043
Dissolved Oxygen	-.257	-.267	.429	.311	.502
Nitrate Nitrogen	.327	.333	.040	.229	-.083
Total Phosphates	.462	.550*	-.106	.063	-.218
pH	.189	.160	.219	.118	.262
Conductivity	-.558*	-.606*	-.821**	-.928**	-.735**
Total Solids	-.413	-.480	-.901**	-.911*	-.857**
Total Vol Solids	-.103	-.166	-.550*	-.524	-.570*
Susp Solids	-.192	.154	-.221	-.037	-.321
Vol Susp Solids	-.262	-.246	-.313	-.157	-.356
Turbidity	-.114	.121	-.721**	-.561	-.781
Total Coliform	-.659*	-.574	.017	-.106	.102
Fecal Coliform	-.105	.055	.125	.087	.140
Fecal Strep	.248	.305	.142	.073	.160

Table D6-5. Continued

Water Quality Parameters	Color IR Green Sensitive Layer	Color Total	Color Red Layer	Color Green Layer	Color Blue Layer
Temperature	.617*	.584	.590	.530	.693
Kjeldahl Nitrogen	-.214	-.311	-.360	-.297	-.342
Biochem Oxygen Dem	.118	.040	.021	.069	.083
Chem Oxygen Dem	-.075	-.222	-.198	-.192	-.304
Dissolved Oxygen	.521	.538	.525	.477	.584
Nitrate Nitrogen	.091	-.034	-.033	.048	-.049
Total Phosphates	.226	-.126	-.124	-.061	-.121
pH	.259	.349	.359	.331	.186
Conductivity	-.727**	-.549*	-.545*	-.589*	-.533*
Total Solids	-.824**	-.567*	-.587*	-.561*	-.533*
Total Vol Solids	-.486	-.429	-.431	-.426	-.414
Susp Solids	-.345	-.130	-.112	-.029	-.132
Vol Susp Solids	-.392	-.093	-.105	-.022	-.022
Turbidity	-.784**	-.585*	-.594*	-.514	-.536*
Total Coliform	.143	.283	.304	.236	.344
Fecal Coliform	.196	.174	.189	.150	.150
Fecal Strep	.178	.057	-.056	-.097	-.121

* Significantly different from zero at the five percent level

** Significantly different from zero at the one percent level

[1] Correlations for the negative type black and white films have opposite signs from the positive type color films.

Table D6-6. CORRELATION COEFFICIENTS FOR ADJUSTED FILM DENSITIES AND WATER QUALITY PARAMETERS FOR AUGUST 9, 1971

Water Quality Parameters	B&W Green Filter #58[1]	B&W Blue Filter #47B[1]	Color IR Total	Color IR Infrared Sensitive Layer	Color IR Red Sensitive Layer
Temperature	-.327	-.307	.346	.327	.353
Kjeldahl Nitrogen	-.031	.192	.039	.114	-.137
Biochem Oxygen Dem	-.178	-.065	.367	.392	.307
Chem Oxygen Dem	.210	.294	-.471	-.460	-.484
Dissolved Oxygen	-.555*	-.493	-.107	-.081	-.082
Nitrate Nitrogen	-.104	-.157	-.455	-.431	-.430
Total Phosphates	-.183	.234	.358	.496	.270
pH	-.570*	-.493	-.612*	-.559*	-.561*
Conductivity	-.195	-.175	-.743**	-.863**	-.657*
Total Solids	-.065	-.094	-.668**	-.769**	-.590*
Total Vol Solids	-.259	-.282	.016	-.106	.114
Susp Solids	.151	.223	-.381	-.307	-.409
Vol Susp Solids	-.084	.020	-.682**	-.585*	-.689**
Turbidity	.110	.080	-.258	-.243	-.241
Total Coliform	-.609*	-.442	-.238	-.223	-.218
Fecal Coliform	-.617*	-.444	-.244	-.228	-.223
Fecal Strep	-.194	-.187	-.015	-.037	-.004

Table D6-6. Continued

Water Quality Parameters	Color IR Green Sensitive Layer	Color Total	Color Red Layer	Color Green Layer	Color Blue Layer
Temperature	.122	-.023	-.076	.037	.022
Kjeldahl Nitrogen	-.048	.043	.054	-.018	-.021
Biochem Oxygen Dem	.287	.177	.018	.179	.090
Chem Oxygen Dem	-.261	-.060	-.031	-.120	-.086
Dissolved Oxygen	-.334	-.384	-.319	-.390	-.314
Nitrate Nitrogen	-.469	-.326	-.194	-.348	-.234
Total Phosphates	.329	.573*	.561*	.552*	.585*
pH	-.641*	-.441	-.244	-.525	-.412
Conductivity	-.521	-.617*	-.532*	-.635*	-.687**
Total Solids	-.421	-.474	-.372	-.495	-.550*
Total Vol Solids	.119	.000	-.014	.050	-.091
Susp Solids	-.258	.105	.162	.035	.139
Vol Susp Solids	-.563*	-.299	-.133	.379	-.239
Turbidity	-.128	-.090	-.021	.084	-.056
Total Coliform	-.457	-.498	-.438	-.482	-.437
Fecal Coliform	-.456	-.493	-.431	-.479	-.437
Fecal Strep	-.146	-.569	-.599	-.471	-.441

* Significantly different from zero at the five percent level

** Significantly different from zero at the one percent level

[1] Correlations for the negative type black and white films have opposite signs from the positive type color films.

Table D6-7. CORRELATION COEFFICIENTS FOR ADJUSTED FILM DENSITIES AND WATER QUALITY PARAMETERS FOR AUGUST 19, 1971

Water Quality Parameters	B&W Green Filter #58	B&W Blue Filter #47B	Color IR Total	Color IR Infrared Sensitive Layer	Color IR Red Sensitive Layer
Temperature	-.598*	-.417	-.448	-.533*	-.354
Kjeldahl Nitrogen	.152	.069	.239	.191	.239
Biochem Oxygen Dem	.177	.301	.309	.115	.360
Chem Oxygen Dem	.091	.147	.243	.145	.272
Dissolved Oxygen	-.357	-.116	.033	-.180	.159
Nitrate Nitrogen	.316	.207	.027	.115	-.049
Total Phosphates	.335	.364	.096	.133	.032
pH	-.396	-.368	-.299	-.316	-.231
Conductivity	-.278	-.401	-.132	-.091	-.094
Total Solids	-.272	-.466	-.177	-.111	-.153
Total Vol Solids	-.385	-.269	-.170	-.315	-.087
Susp Solids	-.185	-.241	-.267	-.217	-.266
Vol Susp Solids	-.028	-.050	-.052	-.051	-.047
Turbidity	.114	-.023	-.048	-.004	-.092
Total Coliform	.370	.372	.170	.169	.115
Fecal Coliform	.369	.373	.172	.168	.118
Fecal Strep	.364	.370	.141	.151	.082

Table D6-7. Continued

Water Quality Parameters	Color IR Green Sensitive Layer	Color Total	Color Red Layer	Color Green Layer	Color Blue Layer
Temperature	-.581*	-.510	-.374	-.457	-.433
Kjeldahl Nitrogen	.331	.209	.137	.168	.083
Biochem Oxygen Dem	.412	.324	.383	.296	.289
Chem Oxygen Dem	.253	.243	.225	.231	.281
Dissolved Oxygen	-.138	-.128	.061	-.153	-.136
Nitrate Nitrogen	.260	.202	.037	.253	.320
Total Phosphates	.367	.273	.160	.316	.441
pH	-.496	-.366	-.272	-.352	-.369
Conductivity	-.392	-.302	-.229	-.359	-.480
Total Solids	-.387	-.314	-.290	-.370	-.504
Total Vol Solids	-.182	-.188	-.109	-.191	-.194
Susp Solids	-.225	-.163	-.277	-.072	-.011
Vol Susp Solids	.022	.033	-.077	.102	.177
Turbidity	.107	.072	-.080	.111	.123
Total Coliform	.423	.317	.223	.342	.412
Fecal Coliform	.423	.317	.225	.341	.411
Fecal Strep	.400	.305	.202	.335	.416

* Significantly different from zero at the five percent level

** Significantly different from zero at the one percent level

[1] Correlations for the negative type black and white films have opposite signs from the positive type color films.

Table D6-8. CORRELATION COEFFICIENTS FOR ADJUSTED FILM DENSITIES AND WATER QUALITY PARAMETERS FOR SEPTEMBER 1, 1971

Water Quality Parameters	B&W Green Filter #58[1]	B&W Blue Filter #47B[1]	Color IR Total	Color IR Infrared Sensitive Layer	Color IR Red Sensitive Layer
Temperature	.021	.258	.300	.216	.322
Kjeldahl Nitrogen	.037	.314	.105	-.067	.185
Biochem Oxygen Dem	.086	.280	.098	-.025	.197
Chem Oxygen Dem	.006	-.042	.151	.204	.133
Dissolved Oxygen	.221	.442	.129	.010	.217
Nitrate Nitrogen	.296	.414	-.113	-.155	-.100
Total Phosphates	.161	.269	.012	.004	-.006
pH	.486	.447	.203	.104	.326
Conductivity	.320	.343	-.147	-.042	-.196
Total Solids	.360	.433	-.179	-.139	-.205
Total Vol Solids	.498	.291	.339	.369	.326
Susp Solids	.286	.211	.129	-.003	.191
Vol Susp Solids	.327	.274	.171	.033	.248
Turbidity	.046	.161	-.408	-.491	-.340
Total Coliform	.187	.469	.142	.082	.201
Fecal Coliform	.158	.428	.144	.098	.193
Fecal Strep	.175	.454	-.041	-.040	-.076

Table D6-8. Continued

Water Quality Parameters	Color IR Green Sensitive Layer	Color Total	Color Red Layer	Color Green Layer	Color Blue Layer
Temperature	.352	-.057	-.147	.000	-.204
Kjeldahl Nitrogen	.212	.008	-.124	-.014	-.232
Biochem Oxygen Dem	.127	.144	.040	.068	-.036
Chem Oxygen Dem	.148	-.085	-.098	-.064	-.155
Dissolved Oxygen	.167	.219	.148	.176	.072
Nitrate Nitrogen	-.023	.400	.461	.450	.433
Total Phosphates	.059	.350	.420	.449	.412
pH	.205	.421	.333	.410	.204
Conductivity	-.207	.334	.477	.415	.540*
Total Solids	-.170	.355	.477	.426	.486
Total Vol Solids	.189	.444	.488	.491	.328
Susp Solids	.208	.461	.457	.480	.346
Vol Susp Solids	.270	.499	.489	.494	.399
Turbidity	-.266	.098	.136	.068	.116
Total Coliform	.133	.074	-.025	.078	-.112
Fecal Coliform	.128	.032	-.069	.049	-.168
Fecal Strep	.016	.179	.216	.304	.151

* Significantly different from zero at the five percent level

** Significantly different from zero at the one percent level

[1] Correlations for the negative type black and white films have opposite signs from the positive type color films.

Table D6-9. CORRELATION COEFFICIENTS FOR ADJUSTED FILM DENSITIES AND WATER QUALITY PARAMETERS FOR NOVEMBER 3, 1971

Water Quality Parameters	B&W Green Filter #58[1]	B&W Blue Filter #47B[1]	Color IR Total	Color IR Infrared Sensitive Layer	Color IR Red Sensitive Layer	Color IR Green Sensitive Layer
Temperature	-.009	.099	-.253	-.340	-.155	-.348
Kjeldahl Nitrogen	-.180	-.100	-.687**	-.157	-.490	-.055
Biochem Oxygen Dem	-.334	-.086	-.600*	-.211	-.462	-.159
Chem Oxygen Dem	-.252	-.094	-.589*	-.281	-.481	-.231
Dissolved Oxygen	.285	.051	.479	.303	-.319	.189
Nitrate Nitrogen	-.034	-.182	.152	.163	.149	.215
Total Phosphates	-.450	.178	-.710**	-.162	-.589*	-.119
pH	.236	.380	.262	.338	.134	.231
Conductivity	-.042	-.251	-.216	.081	-.184	.144
Total Solids	-.181	-.166	-.109	-.217	.048	-.182
Total Vol Solids	.148	-.027	.072	.169	.131	.197
Susp Solids	-.305	-.195	-.564*	-.207	-.597*	-.158
Vol Susp Solids	-.037	-.140	-.549*	-.119	-.498	-.009
Turbidity	-.192	.013	-.236	-.039	-.431	-.104

* Significantly different from zero at the five percent level

** Significantly different from zero at the one percent level

[1] Correlations for the negative type black and white films have opposite signs from the positive type color films.